CIVL 498C: Life Cycle Assessment

FINAL PRESENTATION

April 8th, 2010

overview

TODAY'S PRESENTATION

Introduction
- What is LCA?
- Our Project
- Goal and Scope

Method
- Tools Used
- Building Information
- Model Development

Results & Sensitivity Analysis

Applications and Recommendations

Conclusion

what is lca?

Life Cycle Assessment is...

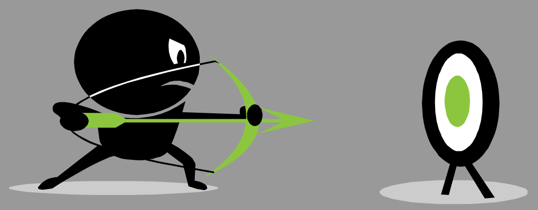
...a science based tool used to measure the environmental impact and performance of products (incl. buildings) over their entire life cycle.

...based on procedures that are part of the International Standards Organization's (ISO) 14040 and ISO 14044.

civil engineering 498c project

- Largest student-run LCA study in North America
- Only known LCA-dedicated undergraduate course in Canada
- 29 academic buildings on UBC Vancouver campus have been modeled by students to date
- Leading Sustainability course at UBC
  - Sustainable Academic Strategy and
  - Living Lab

goal of the study



This study is intended to:

1. establish quantified sustainability guidelines for future UBC construction, renovation, and demolition projects.

2. help decision makers and UBC’s Sustainability Office in creating new policies and frameworks for sustainable development on campus.

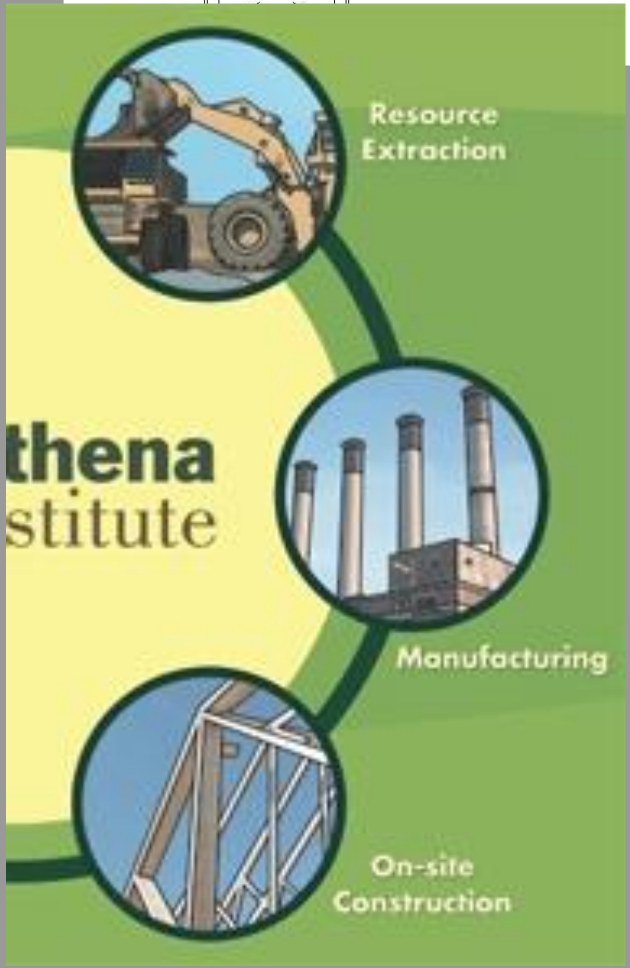
scope of study

WHAT WE CONSIDERED

- Initial building structure and envelope

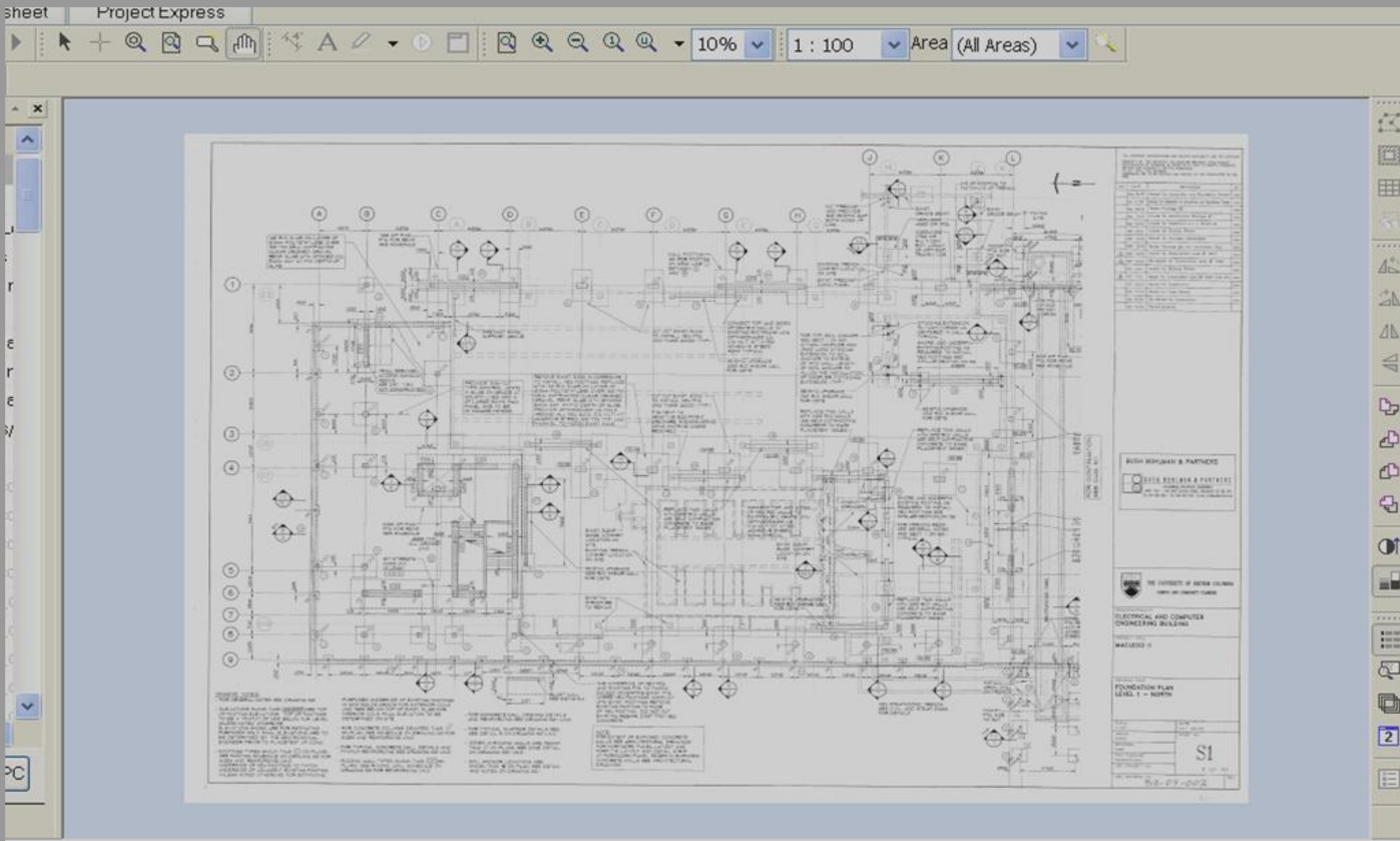
- Functional unit of 1 ft^2 finished floor area of academic building

- Cradle-to-gate



method

BUILDING INFORMATION

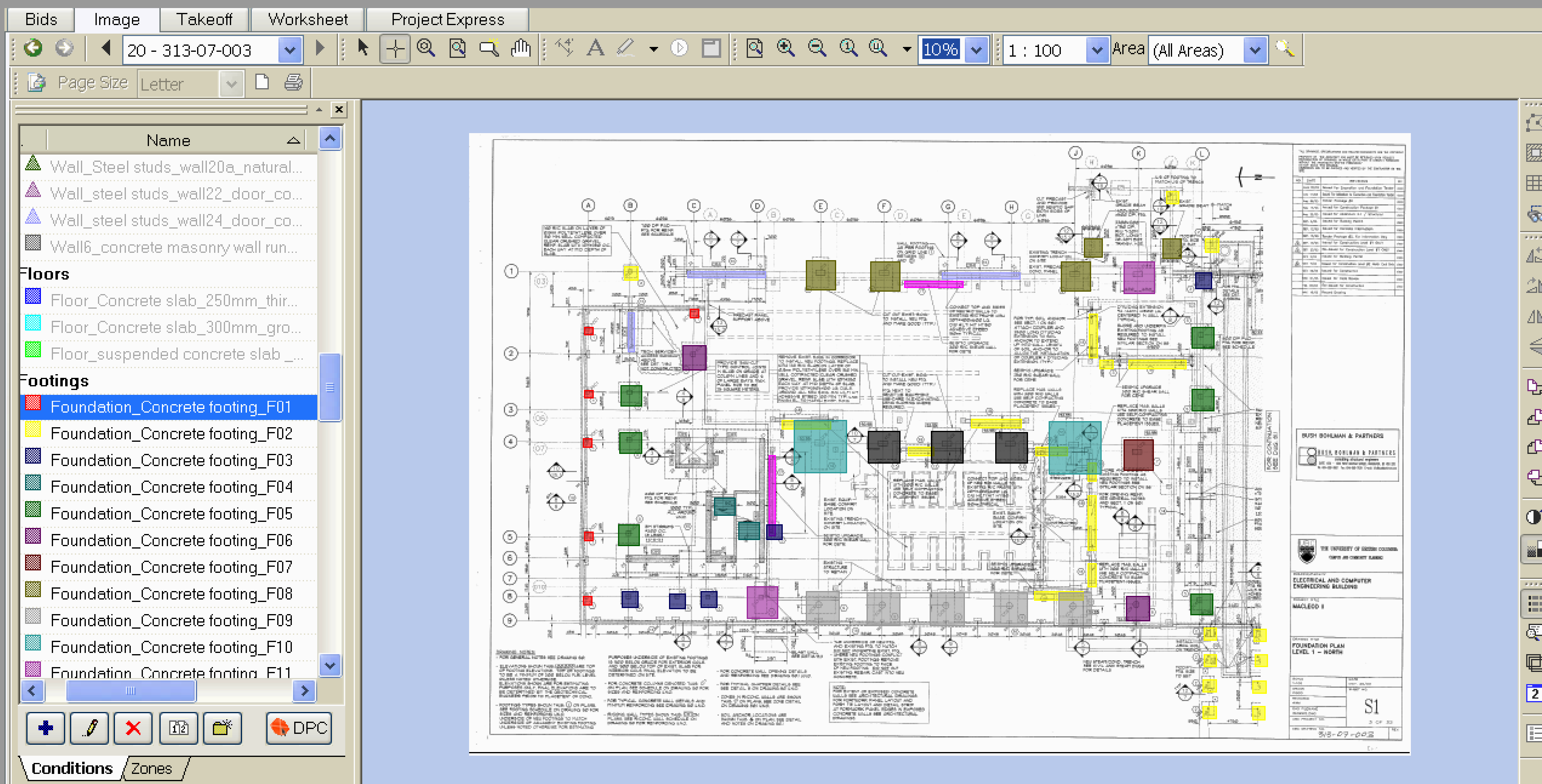


SOURCE: Digital Drawings obtained from UBC campus planning department

method

ONSCREEN TAKEOFF

Footings

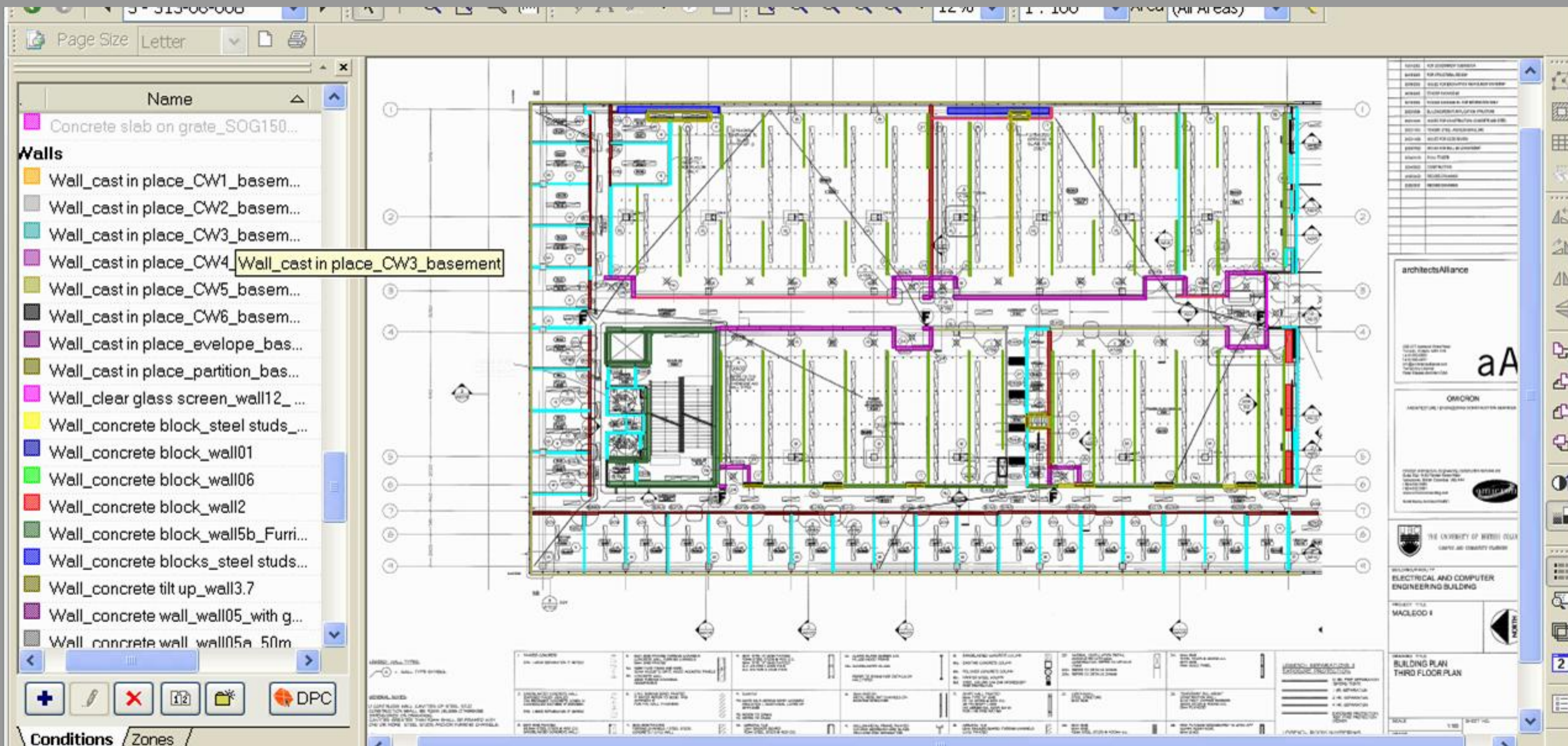


CIVL498C: LIFE CYCLE ASSESSMENT

method

ONSCREEN TAKEOFF

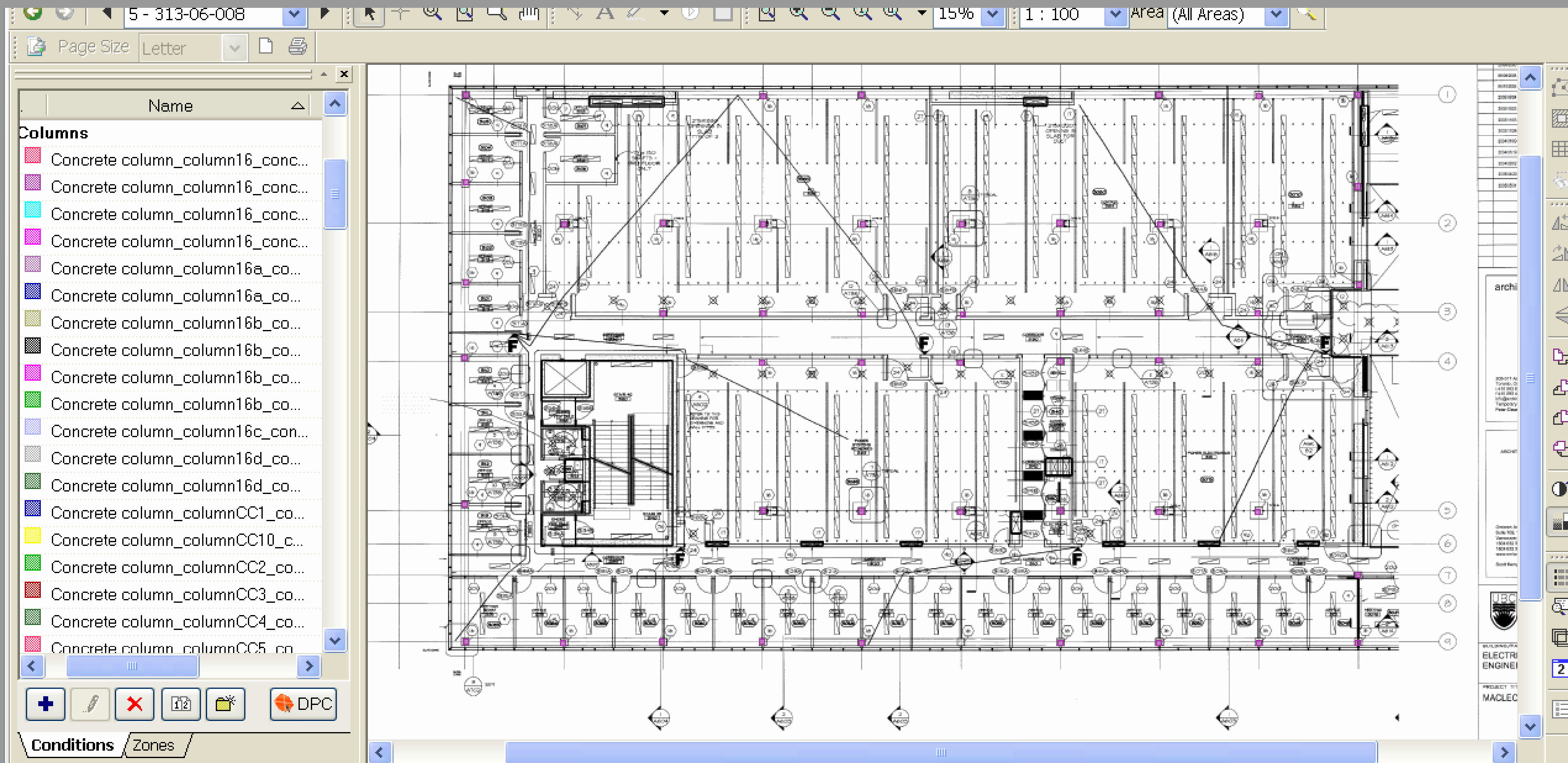
Walls



method

ONSCREEN TAKEOFF

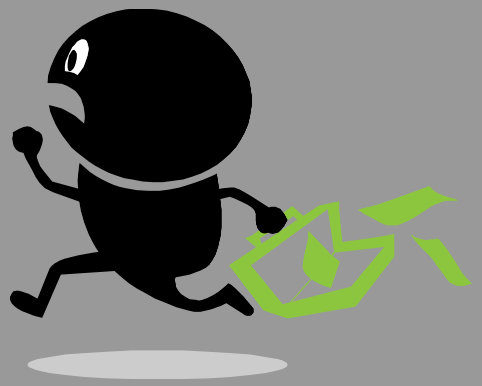
Columns



method

INPUTS & ASSUMPTIONS DOCUMENTS

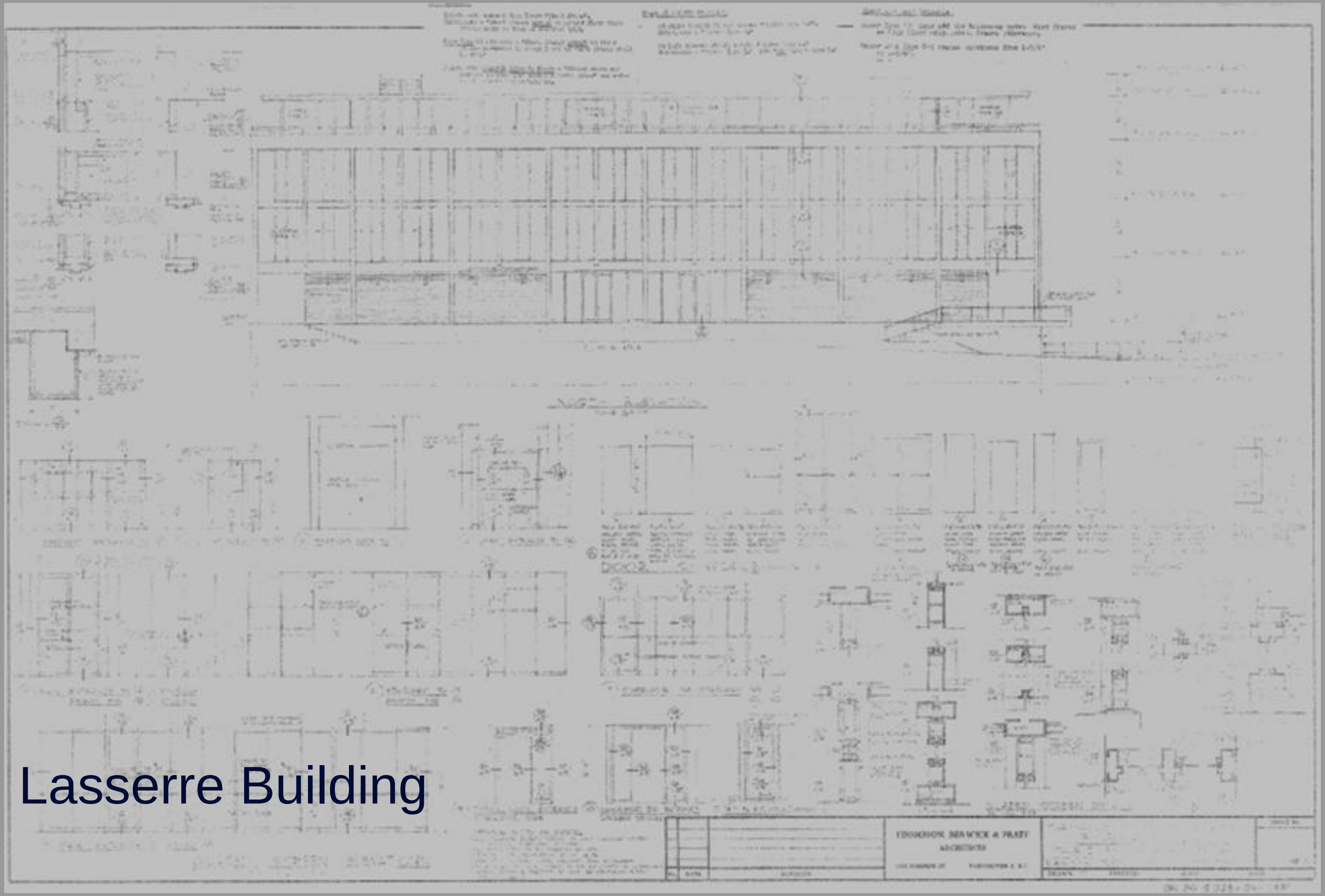
- Extremely important for transparency and reproducibility of study results!
- Contains
  - Interpreted measurements and site visits into IE’s requirements
  - Assumptions that were required to complete models



method

LIMITATIONS

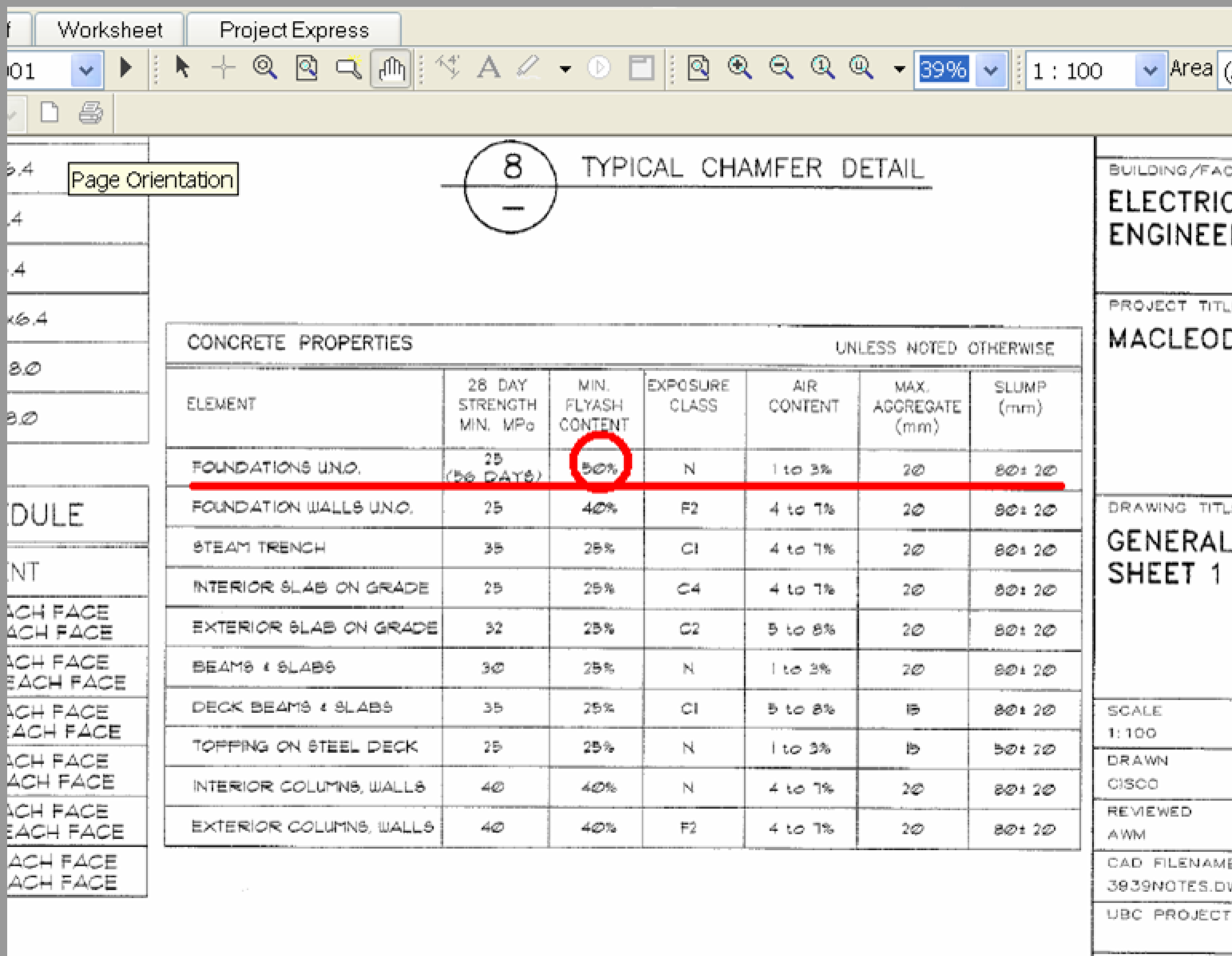
DRAWING CLARITY & MATERIAL SPECIFICATIONS



Lasserre Building

method

EXAMPLE OF ASSUMPTION

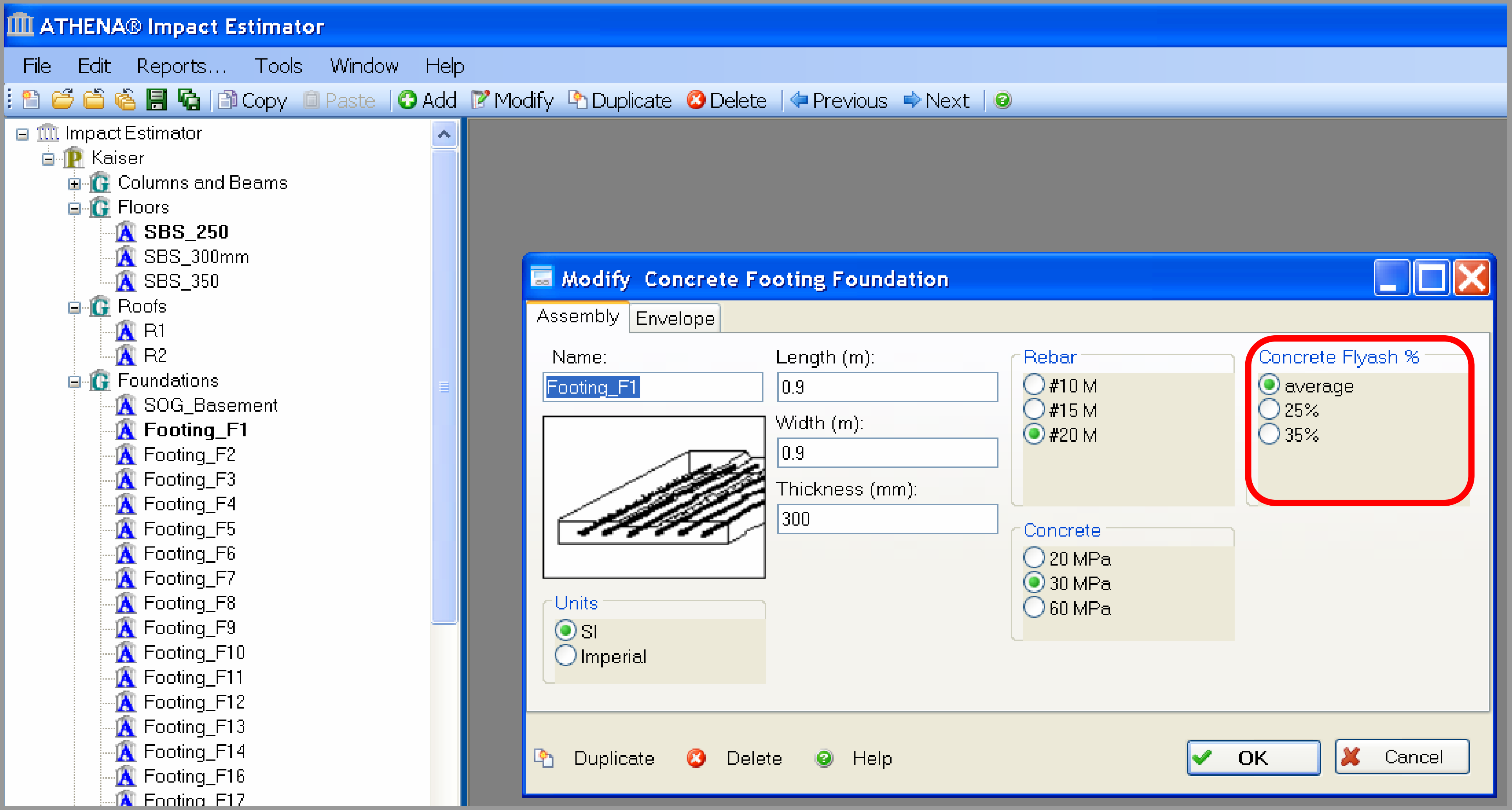


CONCRETE PROPERTIES — UNLESS NOTED OTHERWISE

ELEMENT	28 DAY STRENGTH MIN. MPa	MIN. FLYASH CONTENT	EXPOSURE CLASS	AIR CONTENT	MAX. AGGREGATE (mm)	SLUMP (mm)
FOUNDATIONS U.N.O.	25 (56 DAYS)	50%	N	1 to 3%	20	80± 20
FOUNDATION WALLS U.N.O.	25	40%	F2	4 to 7%	20	80± 20
STEAM TRENCH	35	25%	C1	4 to 7%	20	80± 20
INTERIOR SLAB ON GRADE	25	25%	C4	4 to 7%	20	80± 20
EXTERIOR SLAB ON GRADE	32	25%	C2	5 to 8%	20	80± 20
BEAMS & SLABS	30	25%	N	1 to 3%	20	80± 20
DECK BEAMS & SLABS	35	25%	C1	5 to 8%	15	80± 20
TOPPING ON STEEL DECK	25	25%	N	1 to 3%	15	50± 20
INTERIOR COLUMNS, WALLS	40	40%	N	4 to 7%	20	80± 20
EXTERIOR COLUMNS, WALLS	40	40%	F2	4 to 7%	20	80± 20

method

EXAMPLE OF ASSUMPTION



method

EXAMPLE OF ASSUMPTION

CONCRETE PROPERTIES — UNLESS NOTED OTHERWISE

ELEMENT	28 DAY STRENGTH MIN. MPa	MIN. FLYASH CONTENT	EXPOSURE CLASS	AIR CONTENT	MAX. AGGREGATE (mm)	SLUMP (mm)
FOUNDATIONS U.N.O.	25 (56 DAYS)	50%	N	1 to 3%	20	80± 20
FOUNDATION WALLS U.N.O.	25	40%	F2	4 to 7%	20	80± 20
STEAM TRENCH	35	25%	C1	4 to 7%	20	80± 20
INTERIOR SLAB ON GRADE	25	25%	C4	4 to 7%	20	80± 20
EXTERIOR SLAB ON GRADE	32	25%	C2	5 to 8%	20	80± 20
BEAMS & SLABS	30	25%	N	1 to 3%	20	80± 20
DECK BEAMS & SLABS	35	25%	C1	5 to 8%	15	80± 20
TOPPING ON STEEL DECK	25	25%	N	1 to 3%	15	50± 20
INTERIOR COLUMNS, WALLS	40	40%	N	4 to 7%	20	80± 20
EXTERIOR COLUMNS, WALLS	40	40%	F2	4 to 7%	20	80± 20

ENGINEERIN

PROJECT TITLE
MACLEOD II

DRAWING TITLE
GENERAL NO
SHEET 1

SCALE
1:100

DRAWN
CISCO

REVIEWED
AWM

CAD FILENAME
3939NOTES.DWG

UBC PROJECT NO.

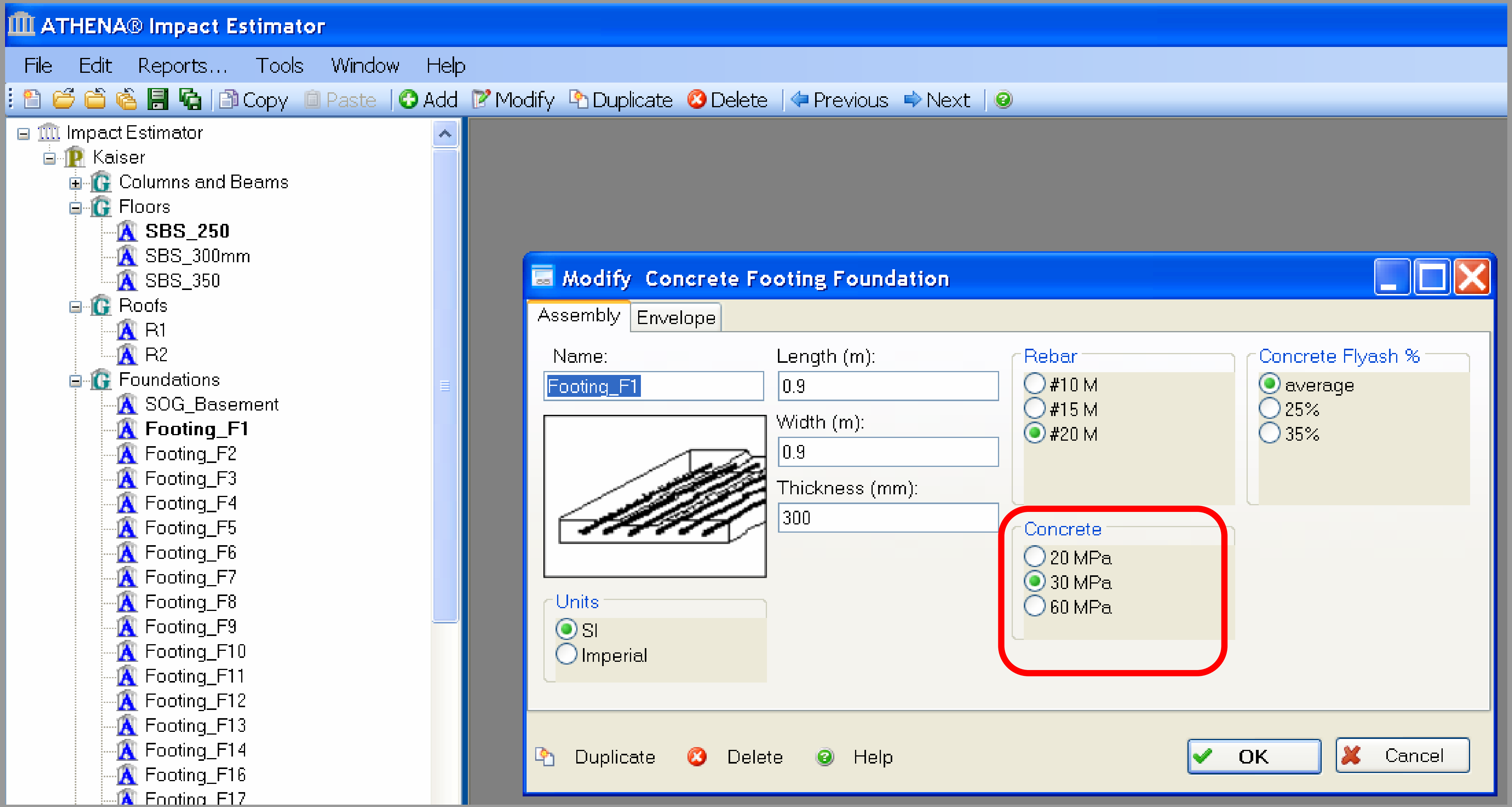
UBC DRAWING NO.
3/3

E

ACE
FACE
ACE
FACE
ACE
FACE
ACE
FACE
ACE
FACE
FACE
FACE

method

EXAMPLE OF ASSUMPTION



method

MODELING PROCESS

Do material takeoffs ← On-Screen Takeoff® – Advanced Takeoff Software

Material building inputs

↓

Generates bill of materials

↓

Outputs Athena LCI profile

(ATHENA® Impact Estimator for buildings)

↓

Applies TRACI v2.2 characterization factors ← TRACI – Tool for the Reduction and Assessment Of Chemical and Other Environmental Impacts

↓

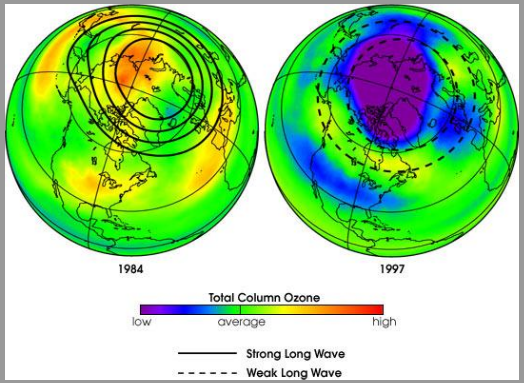
Quantified impacts of building!

Selected Impact Categories

Photochemical Smog Formation

Global Warming Potential

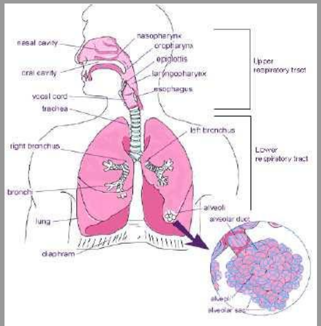
Primary Energy Consumption



Ozone Layer Depletion

Weighted Resource Depletion

Eutrophication Potential



Human Health Respiratory Effects

Acidification Potential

global warming potential

UNITS = KG of CO2 EQUIVALENT

Global warming potential is found by characterizing GHGs emissions by their heat trapping capability relative to CO_2.

The International Panel on Climate Change (IPCC) estimates that the global average sea level will rise between 0.6 and 2 feet (0.18 to 0.59 meters) in the next century.

Vancouver's Predicted Sea Level Rise

More frequent heat waves

B.C. heat wave gets worse

Last Updated: Tuesday, July 28, 2009 | 8:52 PM PT Comments 291 Recommend 154
CBC News

Vancouverites beat the July heat at Stanley Park's Second Beach. (CBC)

High temperatures scorching B.C. reached 40 C in some areas of Vancouver Island on Tuesday, and the mercury is expected to be in the low to mid-30s elsewhere in the south of the province for most of the week.

Usually balmy Port Alberni, about 90 kilometres west of Nanaimo, reached 40 C Tuesday, and the temperature is forecast to hit 40 C on Wednesday.

The high in Port Alberni eclipsed even the frequent provincial hotspot of Osoyoos, in the Southern Interior, which hit 37 C on Tuesday.

When it gets hot in Port Alberni, many residents head for Sproat Lake, about 10 kilometres west of town.

'Honestly, it's like almost unbearable.'
—Regan Lindors, Sproat Lake Marine Patrol

aquatic eutrophication

UNITS = KG of NITROGEN EQUIVALENT

Aquatic Eutrophication refers to the fertilizing of surface waters by nutrients that were previously scarce through the discharge of waste water into the environment.

- Death of fish and shell fish
- Undesirable for recreation, industry, and drinking
- Can be toxic to humans, fish, and livestock
- Reduces overall biodiversity

acidification

UNITS = MOLES of H+ EQUIVALENT

Acidification is a regional impact determined by quantifying the mass of of SO_2 and NOx and characterizing these emissions in terms of their potential to produce H^+ ions.

According to Environment Canada, B.C. is particularly susceptible to acidification because the geology does not have the capacity to *neutralize* acid.

smog potential

UNITS = KG of NOx EQUIVALENT

Smog is the common name for ground level ozone formed through a complex reaction of VOCs and NOx in the presence of sunlight.

"The Ministry of Environment is reminding people with heart or breathing conditions to consider reducing or rescheduling strenuous outdoor activities if they experience symptoms such as coughing and throat irritation."

Lower Mainland air quality remains poor

BY REBECCA TEBRAKE, VANCOUVER SUN AUGUST 1, 2009

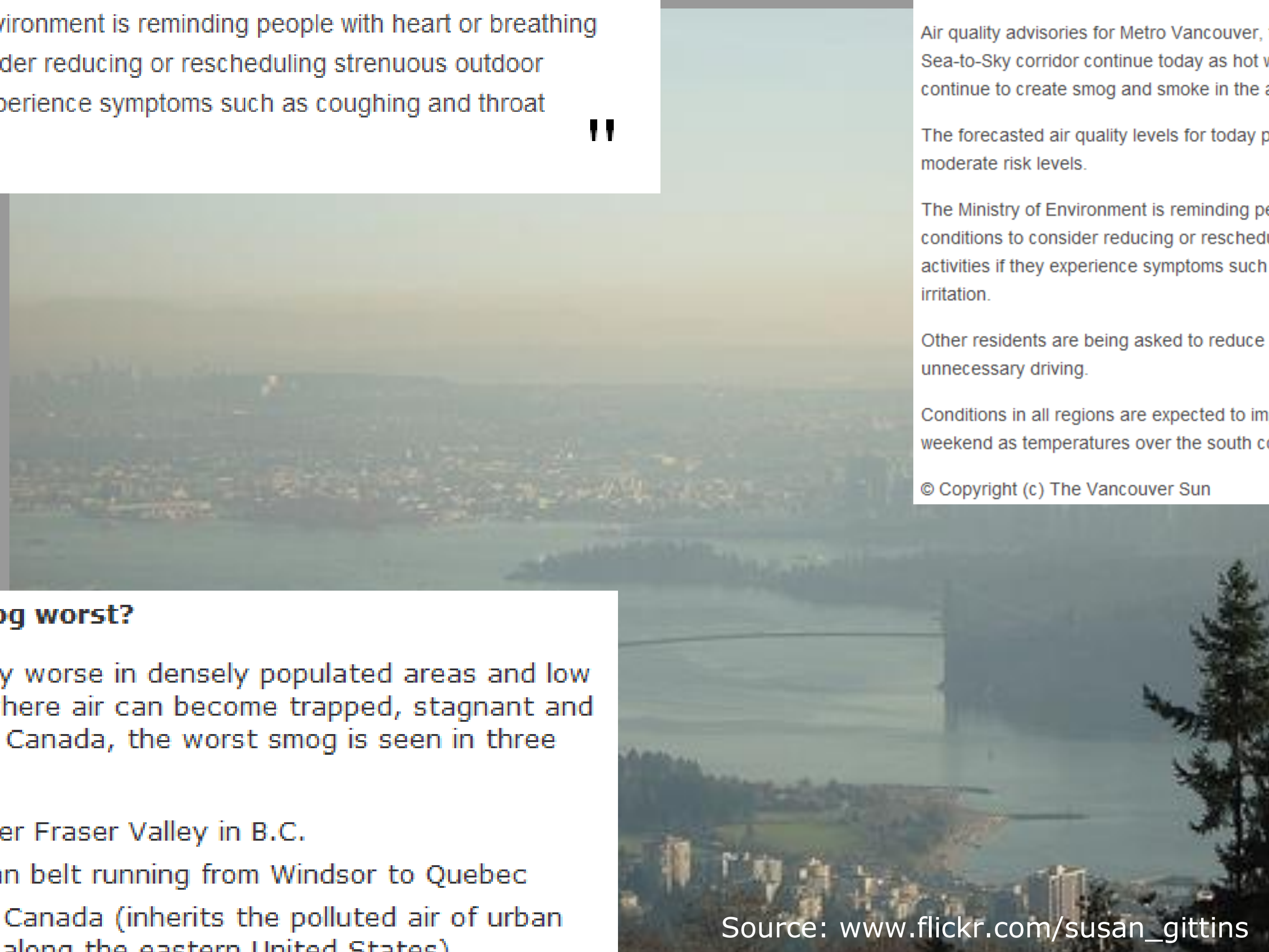
Air quality advisories for Metro Vancouver, the Fraser Valley and the Sea-to-Sky corridor continue today as hot weather and forest fires continue to create smog and smoke in the area.

The forecasted air quality levels for today peak at a rating of five, or moderate risk levels.

The Ministry of Environment is reminding people with heart or breathing conditions to consider reducing or rescheduling strenuous outdoor activities if they experience symptoms such as coughing and throat irritation.

Other residents are being asked to reduce emissions by cutting out unnecessary driving.

Conditions in all regions are expected to improve throughout the long weekend as temperatures over the south coast drop.



Source: www.flickr.com/susan_gittins

Where is smog worst?

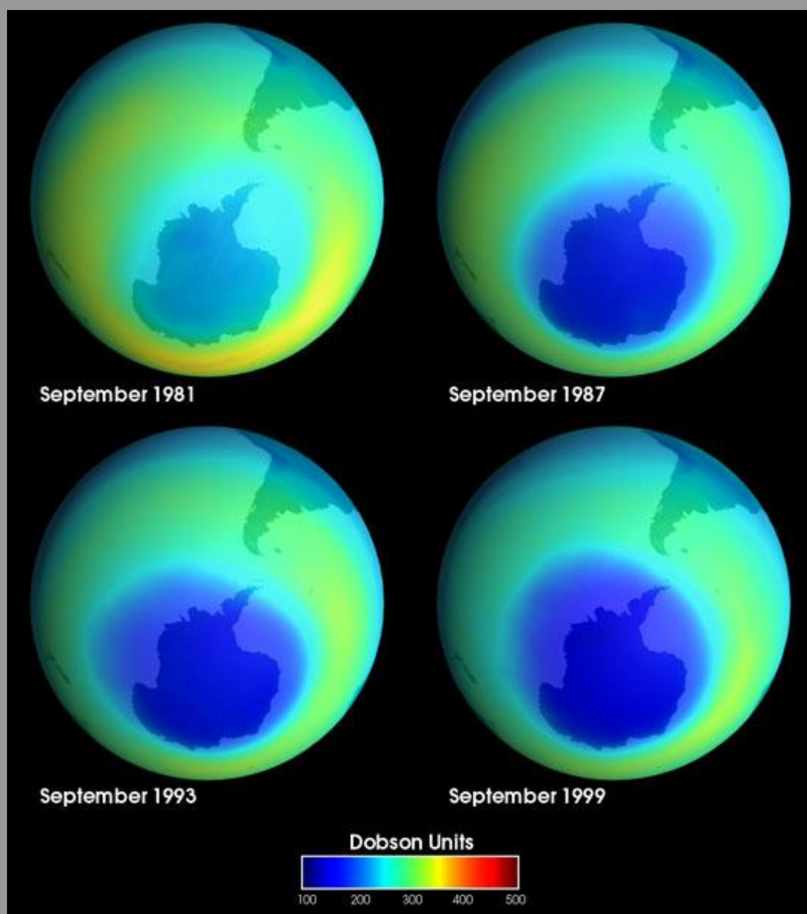
Smog is usually worse in densely populated areas and low valley areas where air can become trapped, stagnant and very warm. In Canada, the worst smog is seen in three areas:

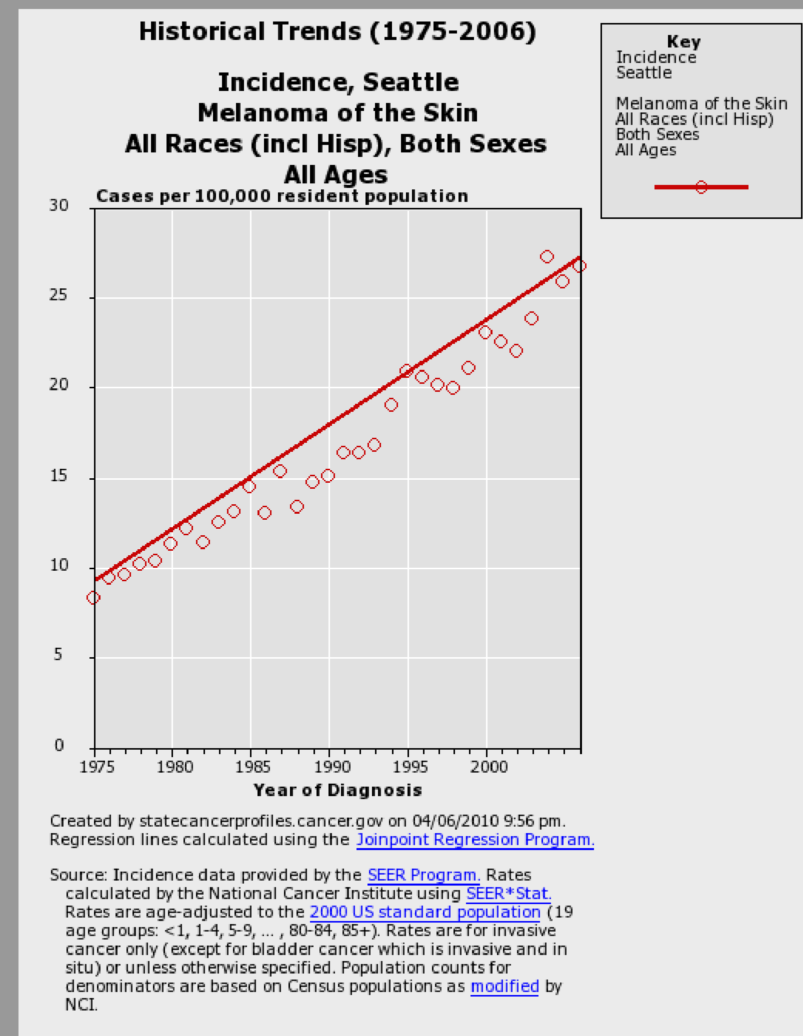
- the Lower Fraser Valley in B.C.
- the urban belt running from Windsor to Quebec
- Atlantic Canada (inherits the polluted air of urban centres along the eastern United States)

ozone depletion

UNITS = KG of CFC-11 EQUIVALENT

Ozone depletion potential accounts for air emissions that reduce the protective ozone layer within the stratosphere. Other substances like hydrofluorocarbons (HFC's), and halons are measured and given a factor to translate their impacts to equivalent kilograms of CFC's. (Athena Version 4.0.64)

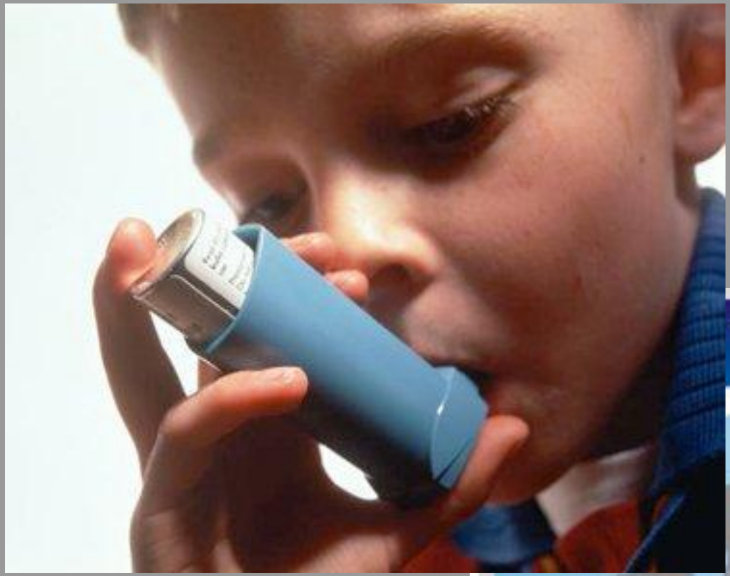


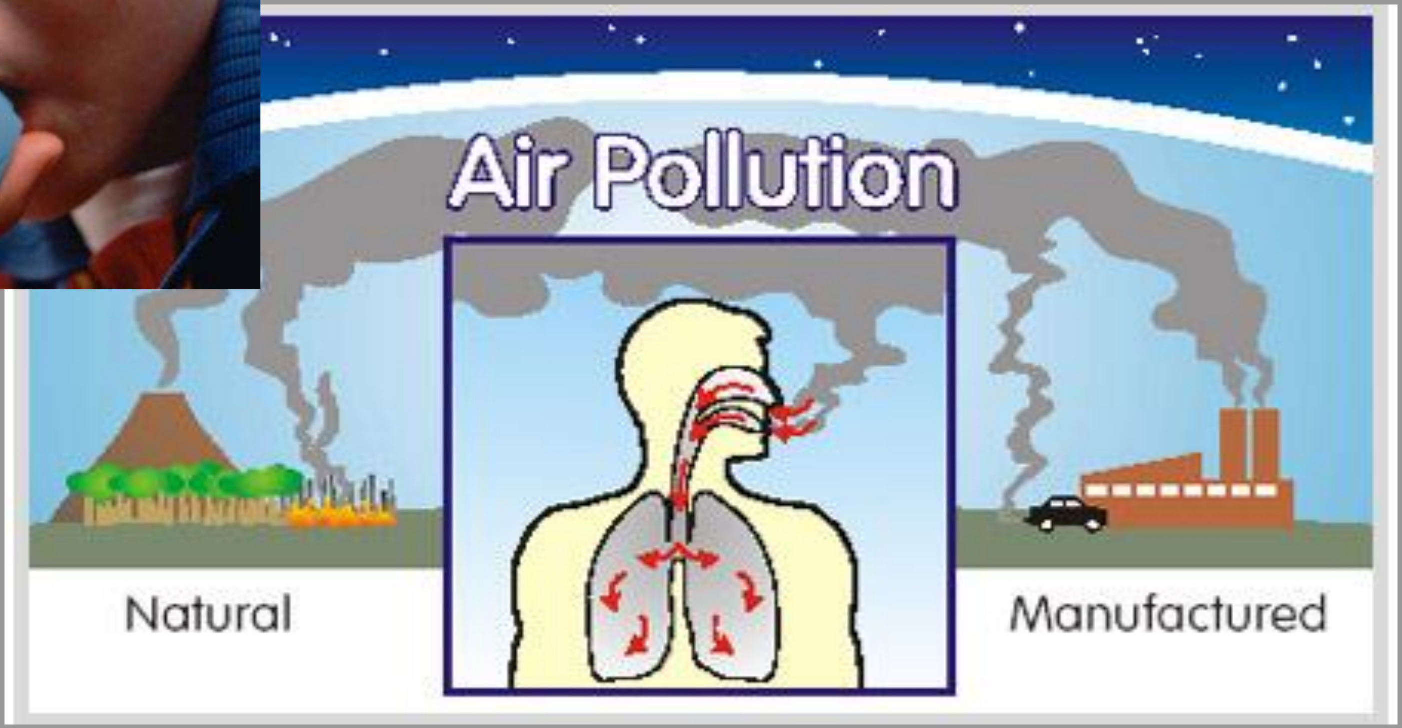


human health respiratory effects potential

UNITS = KG of PM2.5 EQUIVALENT

Measures masses of the same size particle for a given material and applies a factor to get the given size to 2.5µm equivalence.





primary energy consumption

UNITS = MEGAJOULES (MJ)

Includes all energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. The IE also includes energy required for, processing, transporting, converting and delivering fuel and energy. (Athena Version 4.0.64)

Forest Sciences Center's Primary Energy Consumption

59,340,113 MJ

=

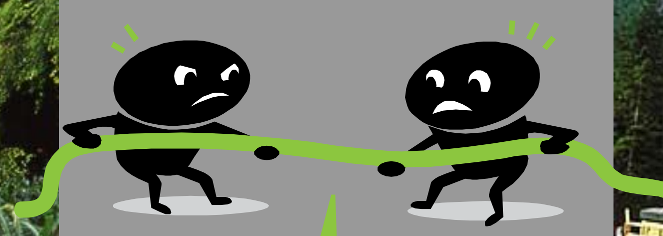
Power used to heat 500 typical Canadian homes for 13.5 months.

weighted resource use

UNITS = KG

Weighted resource use, measured in kg, can be thought of as "ecologically weighted kilograms".

Applies a factor to the quantity of resource extracted to quantify the effects on things like bio-diversity, ground water quality and wildlife habitat.



Results of Our Study

results

LIMITATIONS

- Preliminary results
- Structure and envelope
- Cradle-to-gate
- Non-regionalized Impact Assessment
- Data vintage
  - Life cycle inventory (LCI) data
  - Impact characterization

results

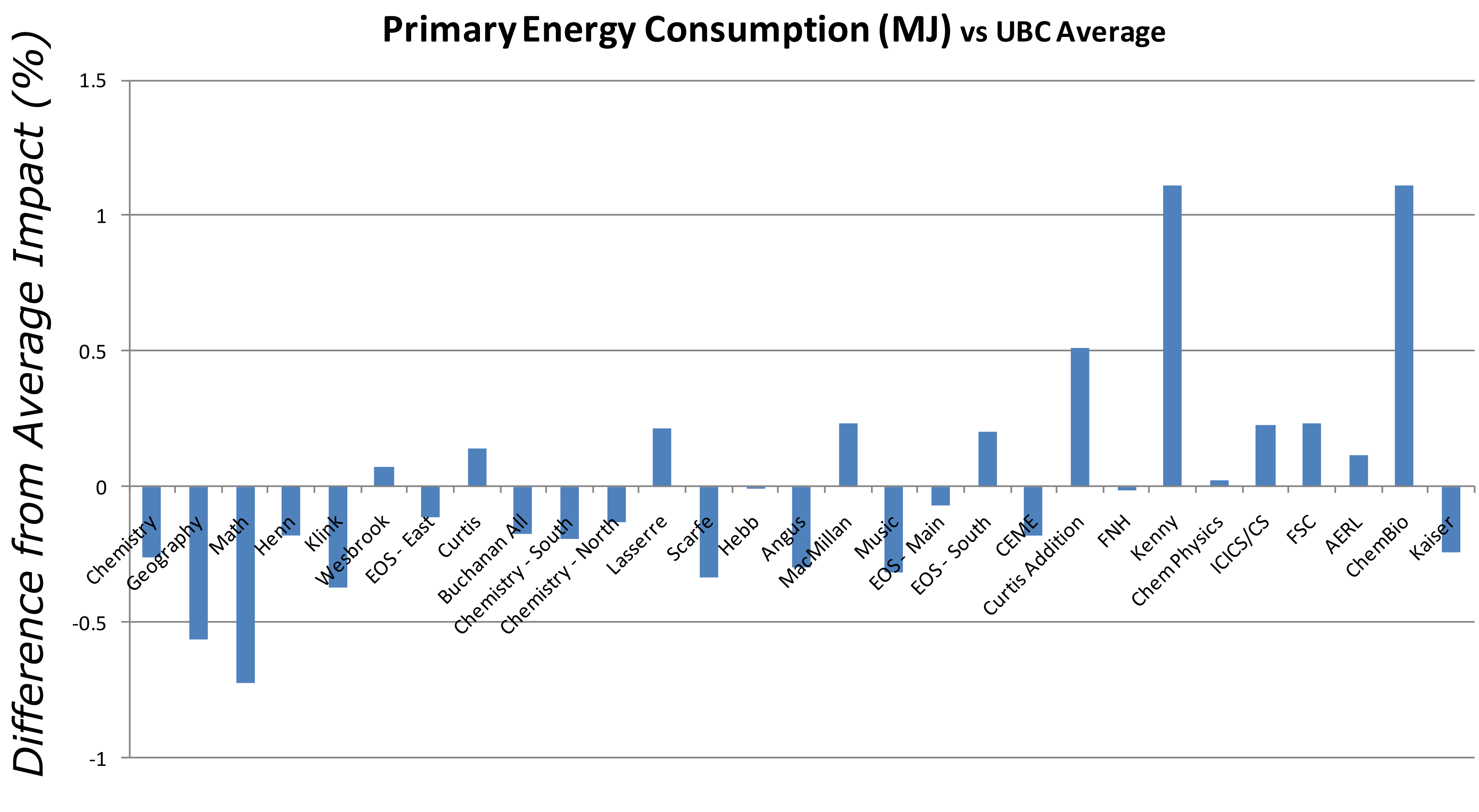
AVERAGE IMPACT OF UBC ACADEMIC BUILDINGS

Impact Category	Units	Average Impact
Primary Energy Consumption	MJ)	2.91E+02
Weighted Resource Use	(kg)	1.62E+02
Global Warming Potential	(kg CO2 eq)	2.44E+01
Acidification Potential	(moles H+ eq)	1.01E+01
HH Respiratory Effects Potential	(kg PM2.5 eq)	8.06E-02
Eutrophication Potential	(kg N eq)	1.01E-02
Ozone Depletion Potential	(kg CFC-11 eq)	5.48E-08
Smog Potential	(kg NOx eq)	1.19E-01

CIVL498C: LIFE CYCLE ASSESSMENT

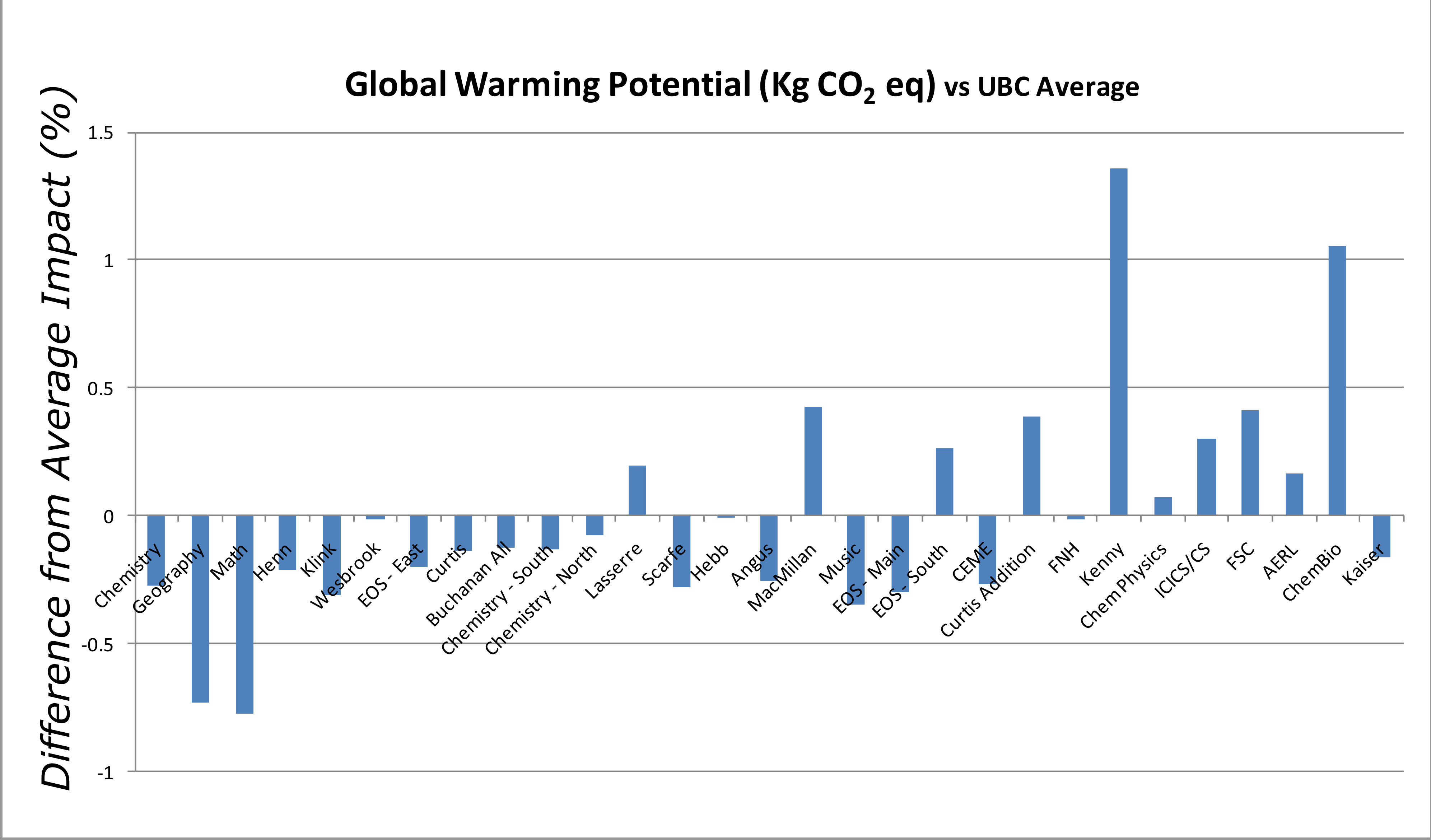
results

PRIMARY ENERGY CONSUMPTION



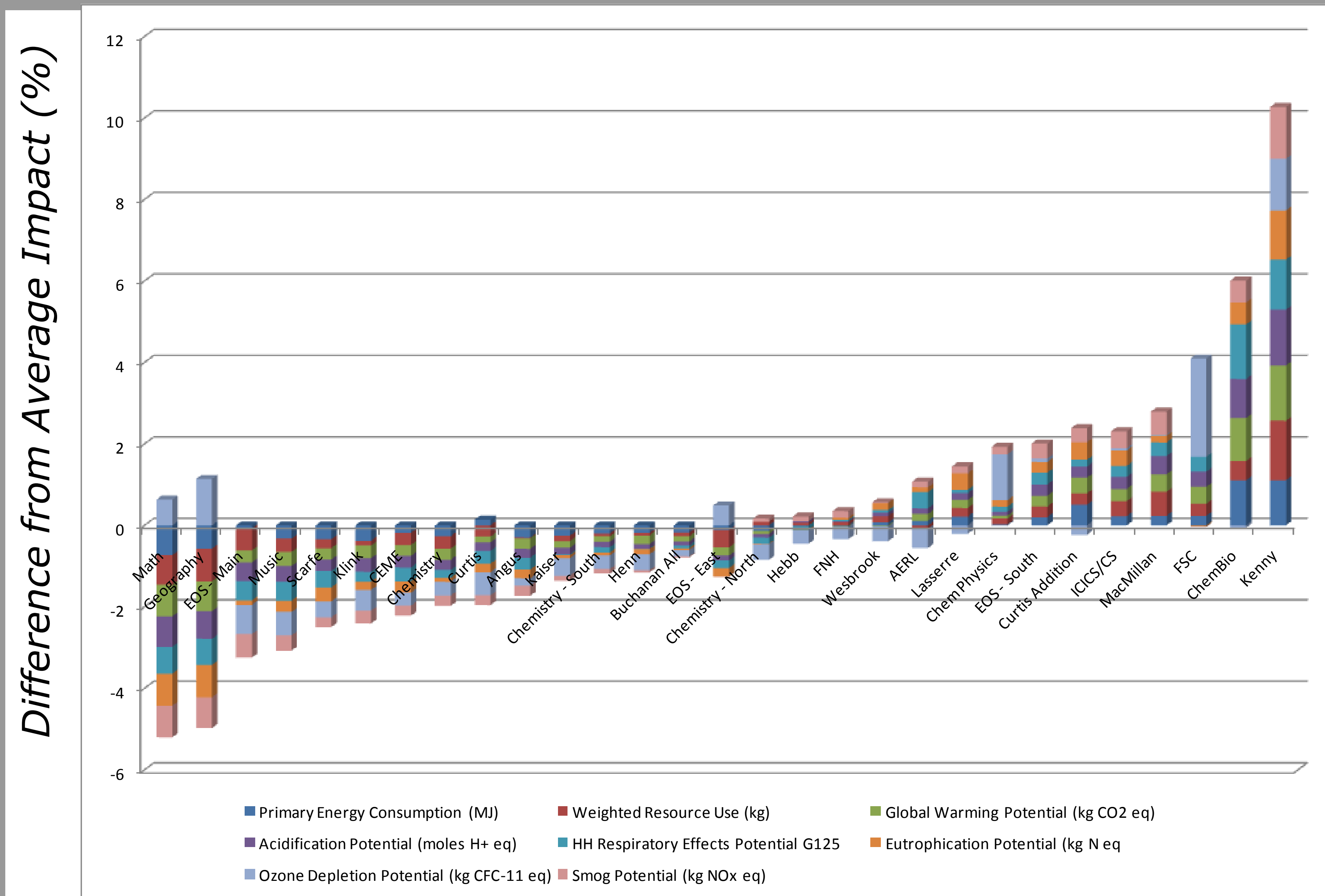
results

GLOBAL WARMING POTENTIAL



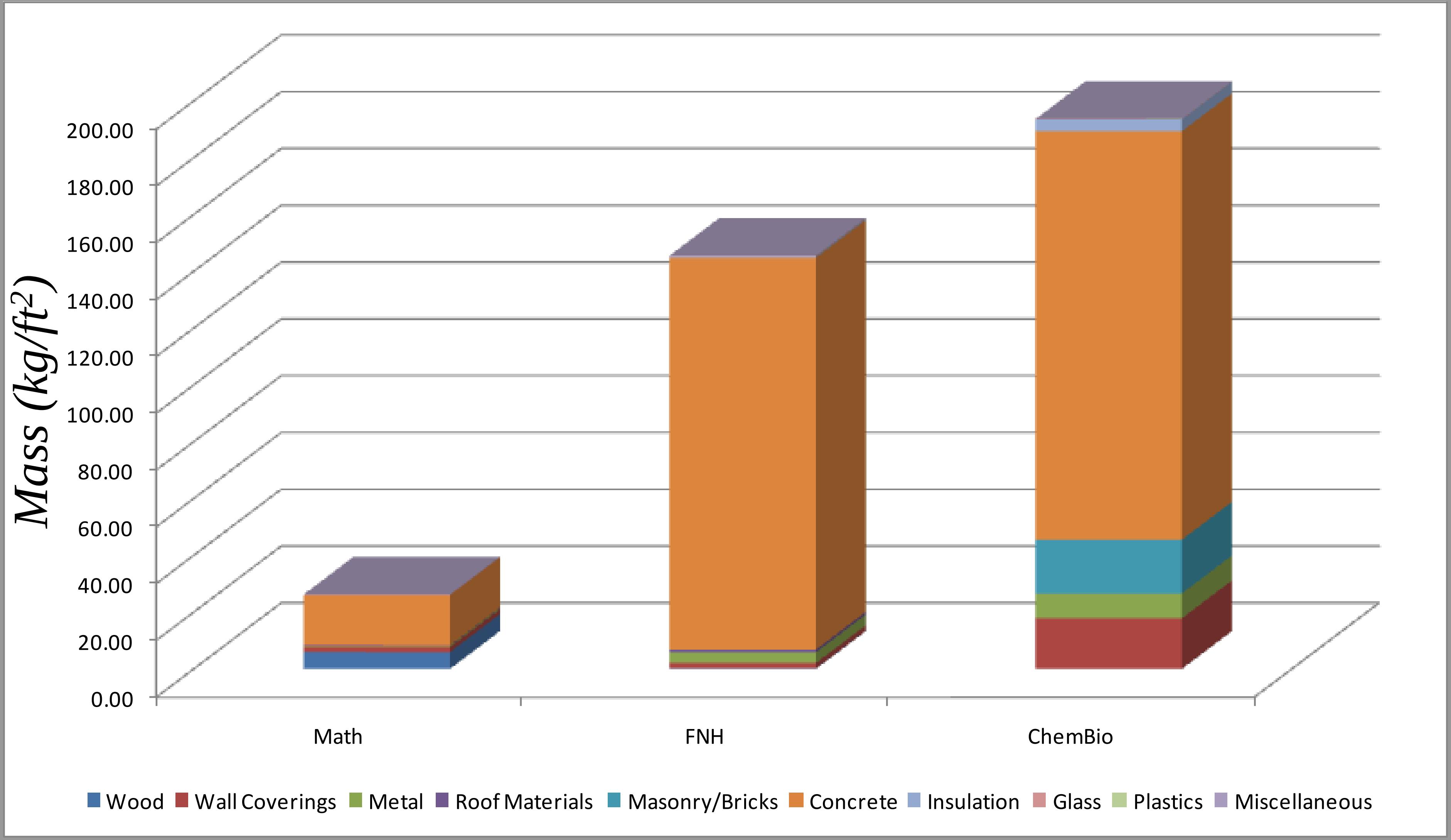
results

OVERALL: DIFFERENCE FROM AVERAGE



results

MATERIAL CHOICES CAUSE IMPACTS

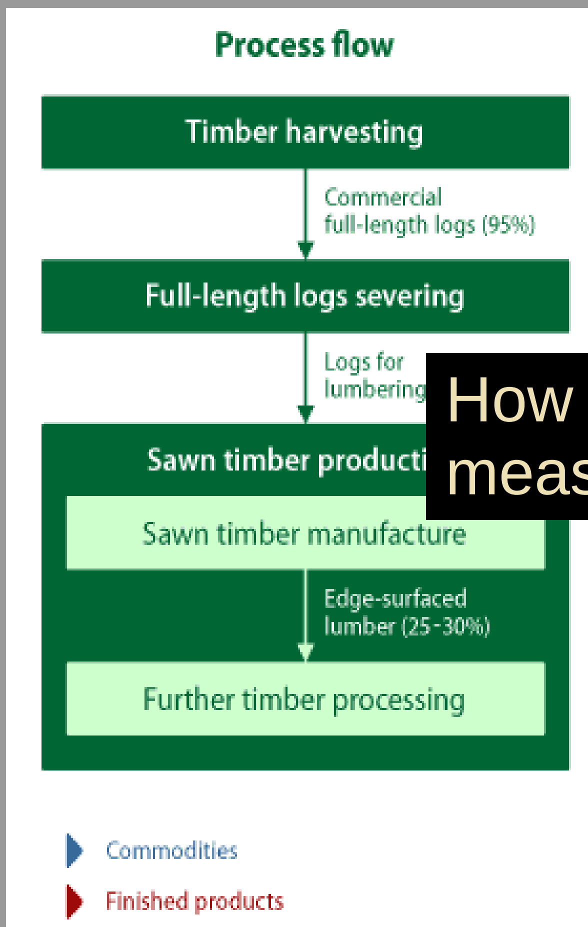


potential impacts of construction materials

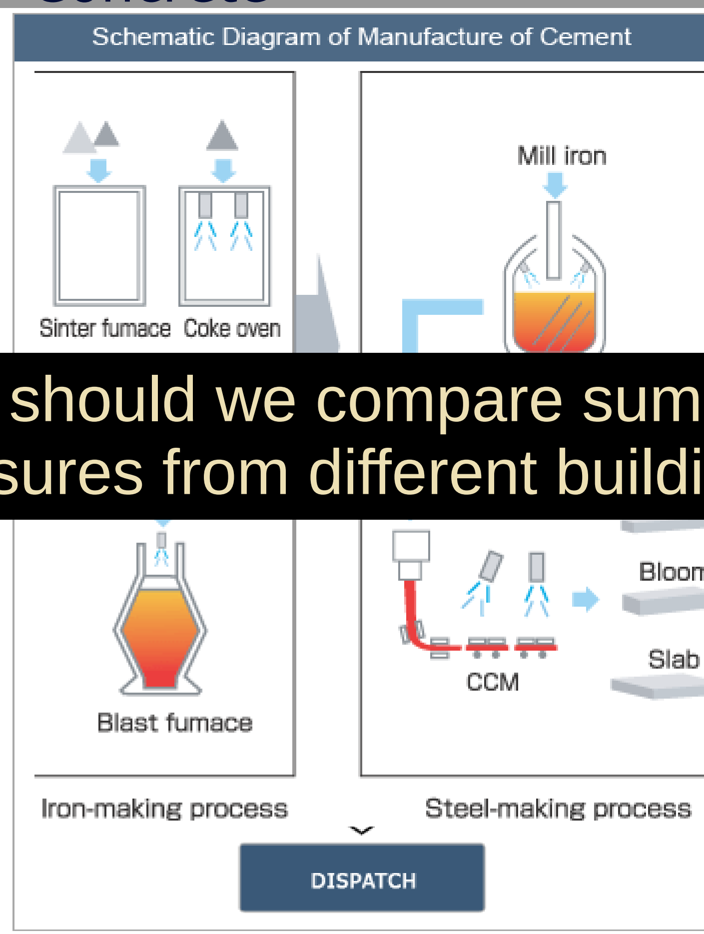
Summary measures of a building are determined by the construction materials used. Measures are computed from raw resource extraction to construction.

Consider the production of:

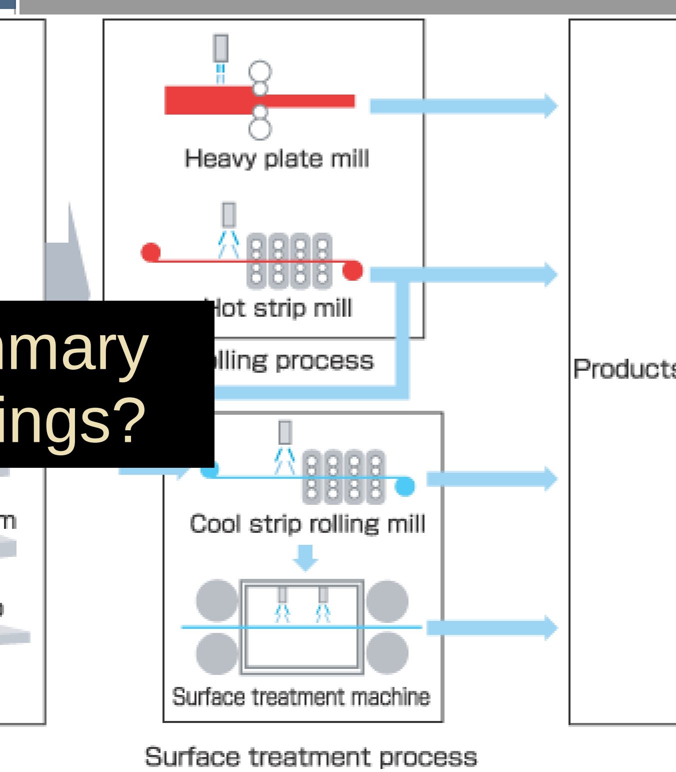
Timber



Concrete



Metal



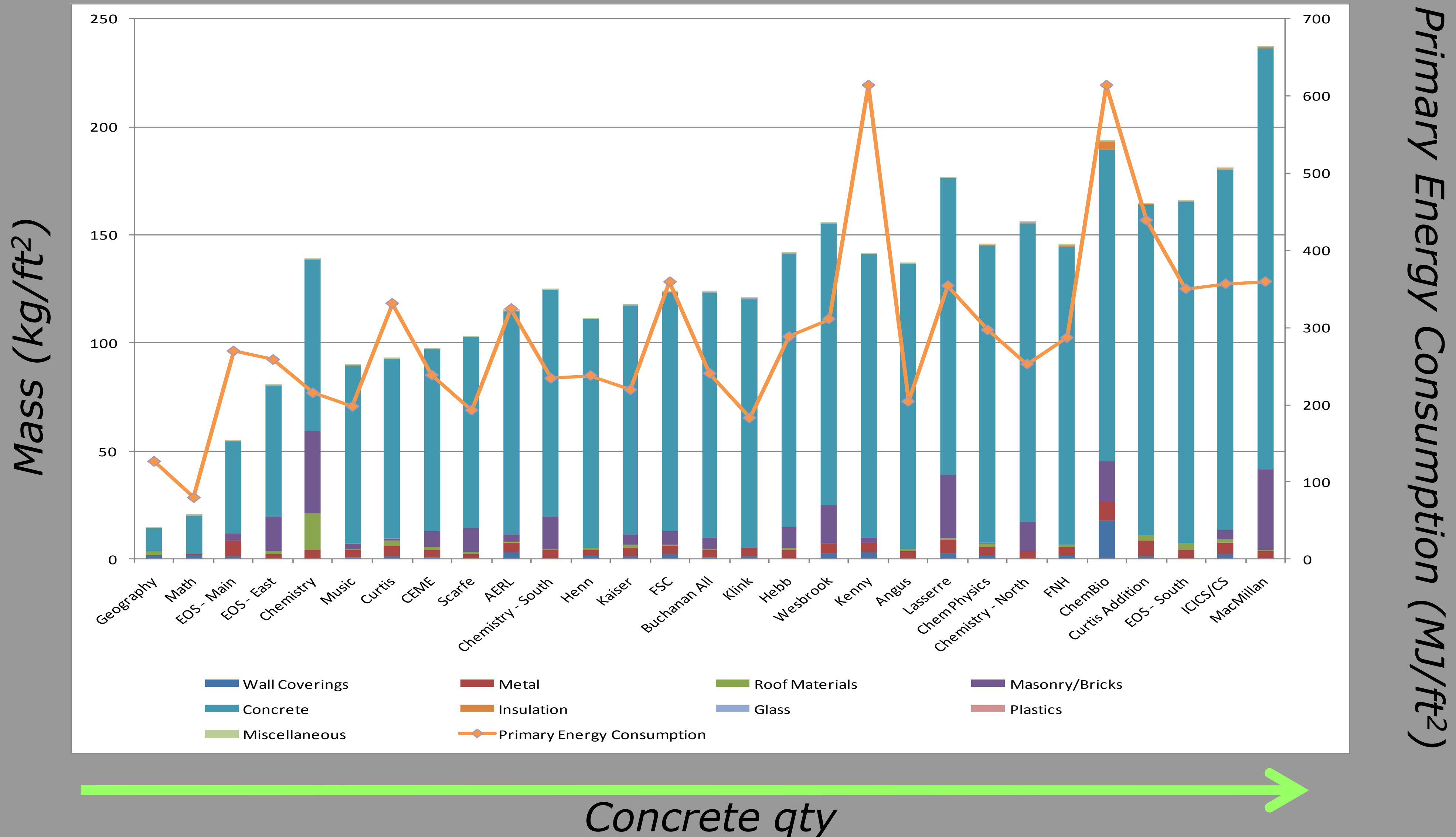
How should we compare summary measures from different buildings?

CIVL498C: LIFE CYCLE ASSESSMENT

results

PRIMARY ENERGY CONSUMPTION

Ranked by concrete

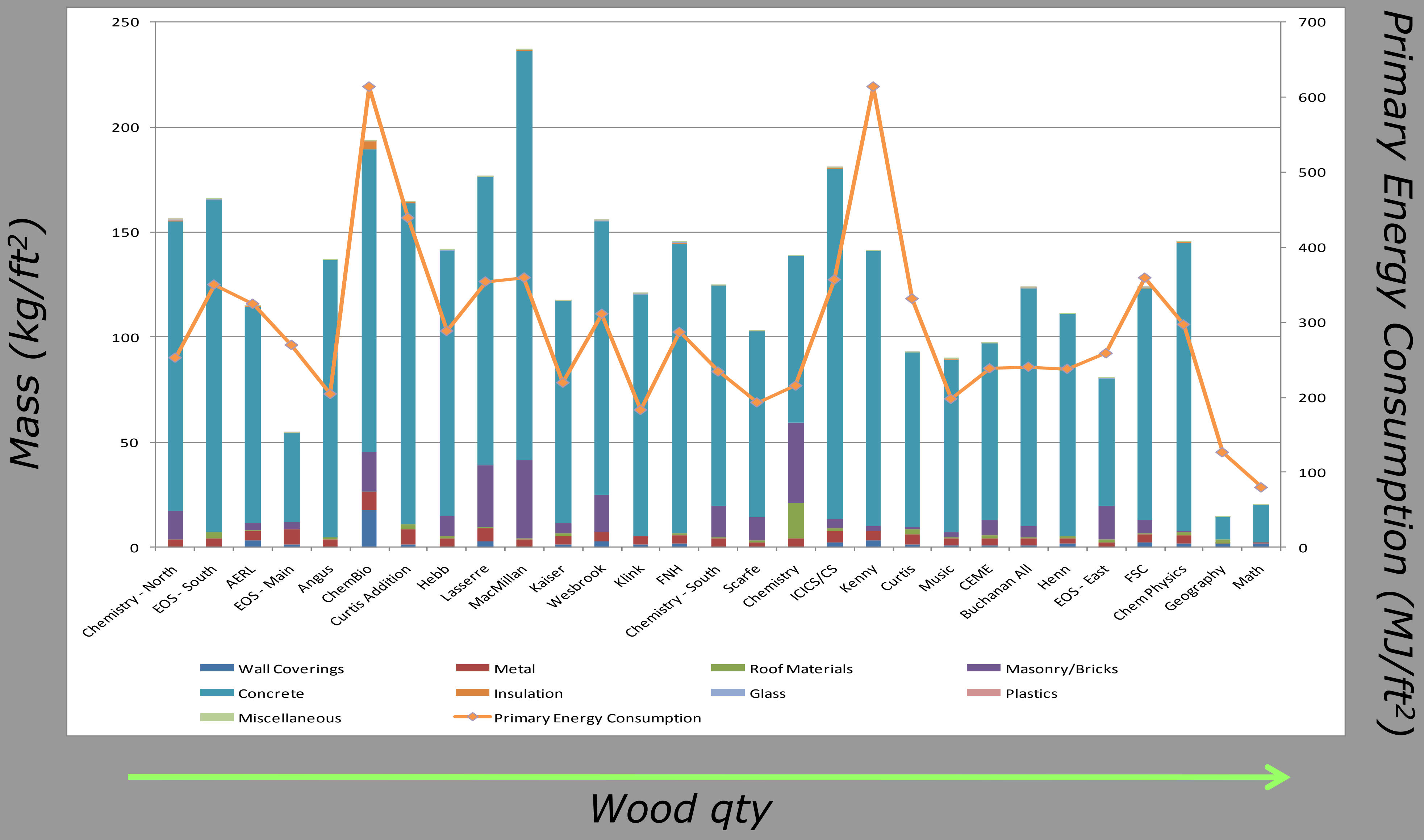


CIVL498C: LIFE CYCLE ASSESSMENT

results

PRIMARY ENERGY CONSUMPTION

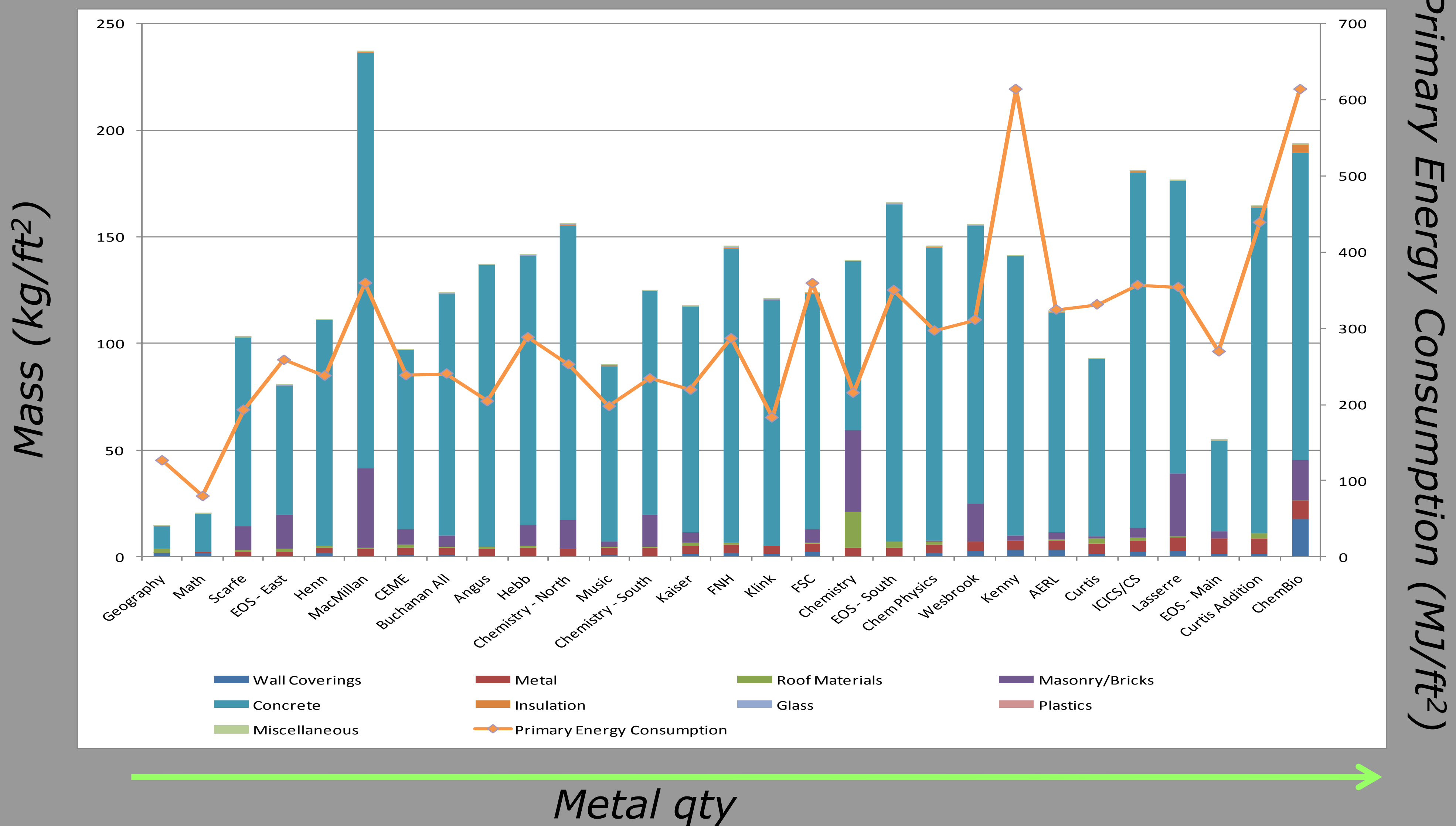
Ranked by wood



results

PRIMARY ENERGY CONSUMPTION

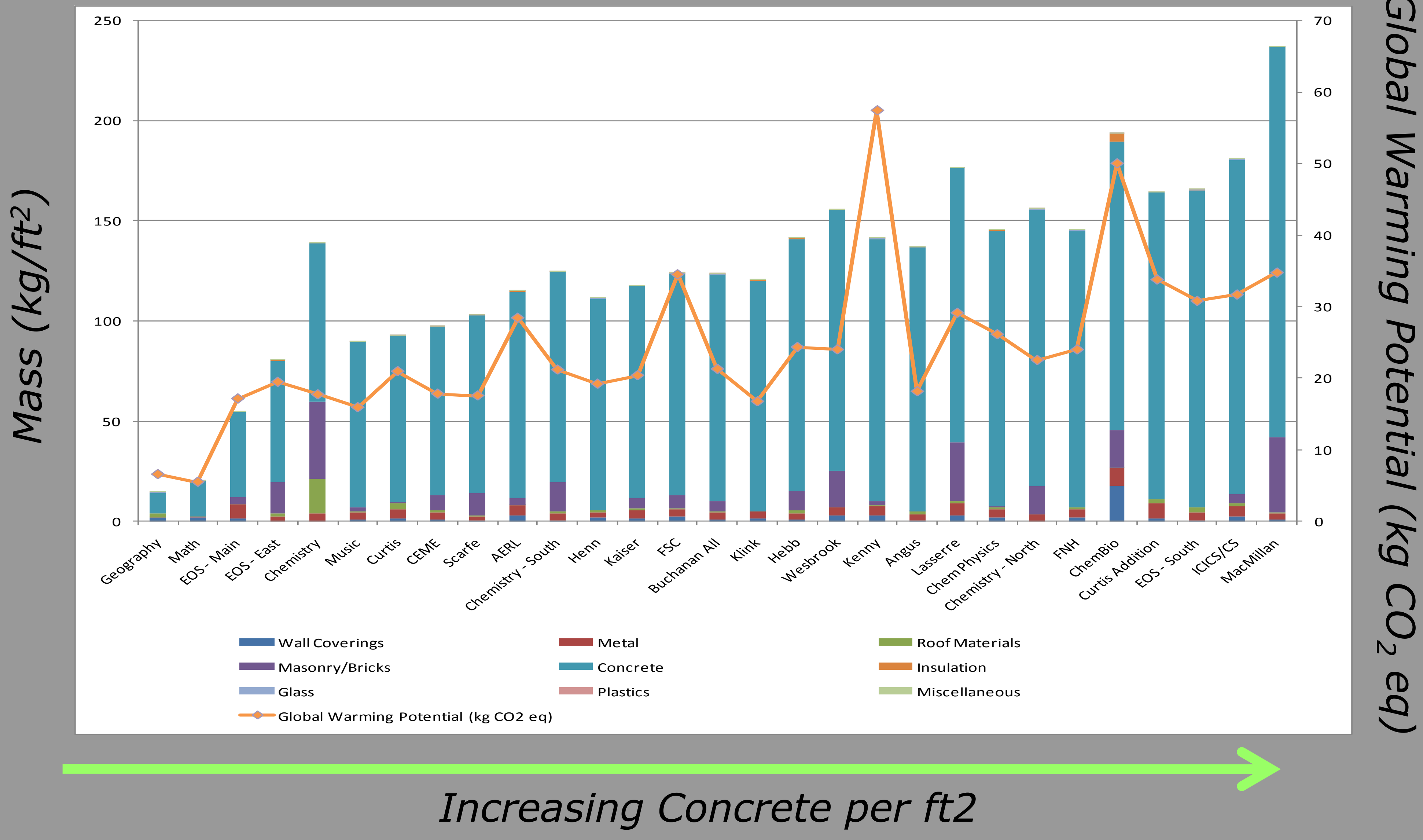
Ranked by metal



results

GLOBAL WARMING POTENTIAL

Ranked by concrete

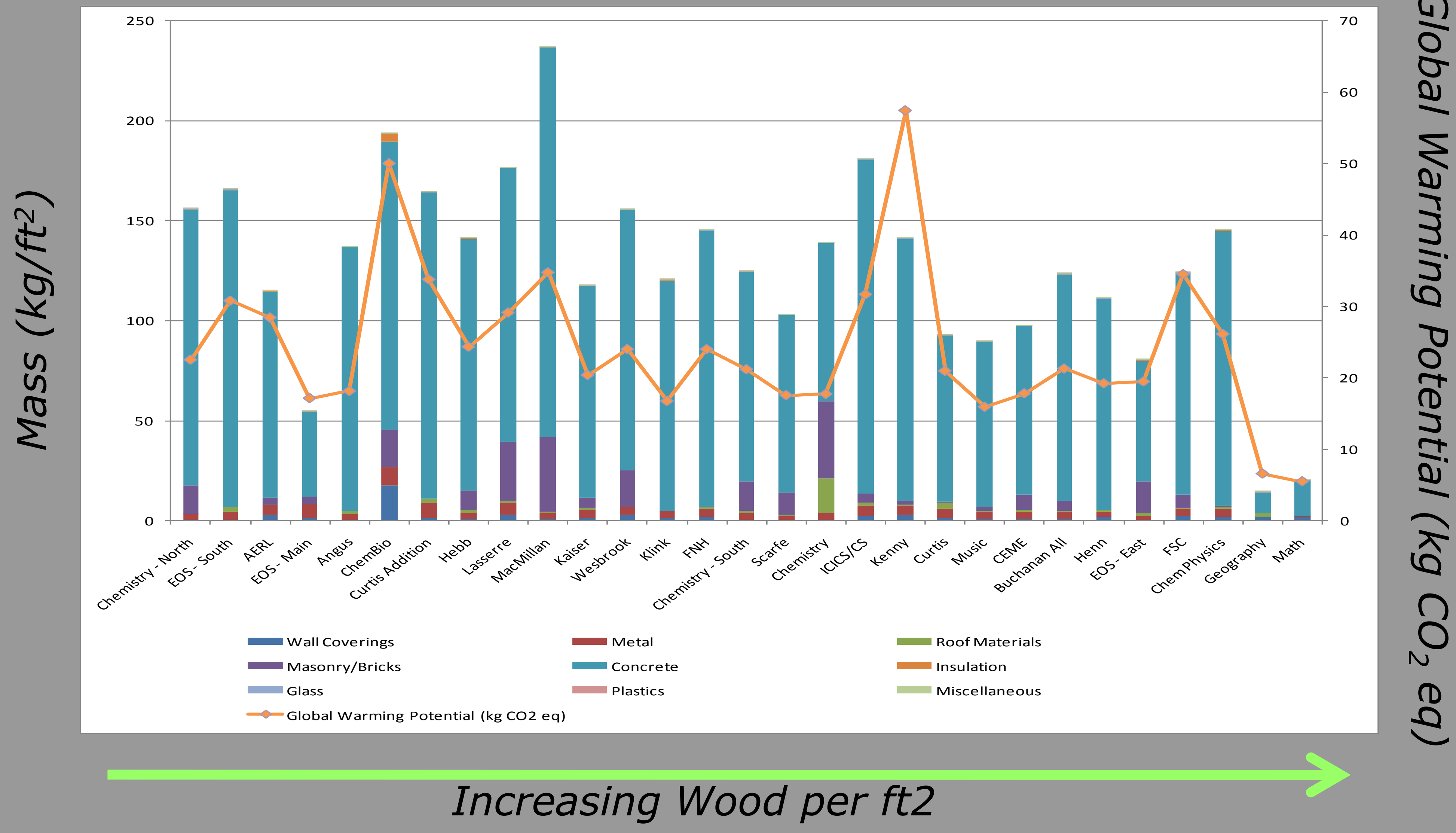


CIVL498C: LIFE CYCLE ASSESSMENT

results

GLOBAL WARMING POTENTIAL

Ranked by wood

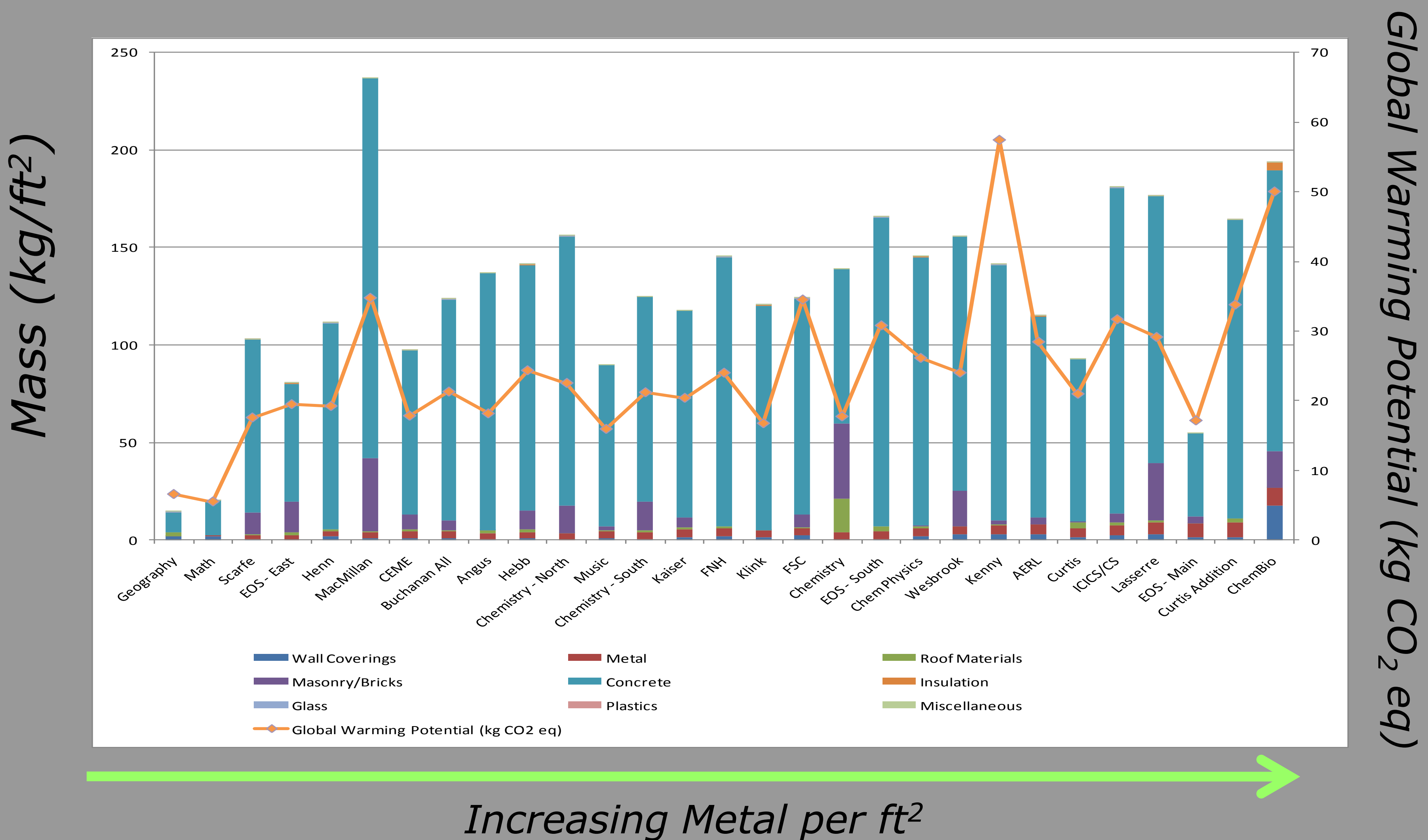


CIVL498C: LIFE CYCLE ASSESSMENT

results

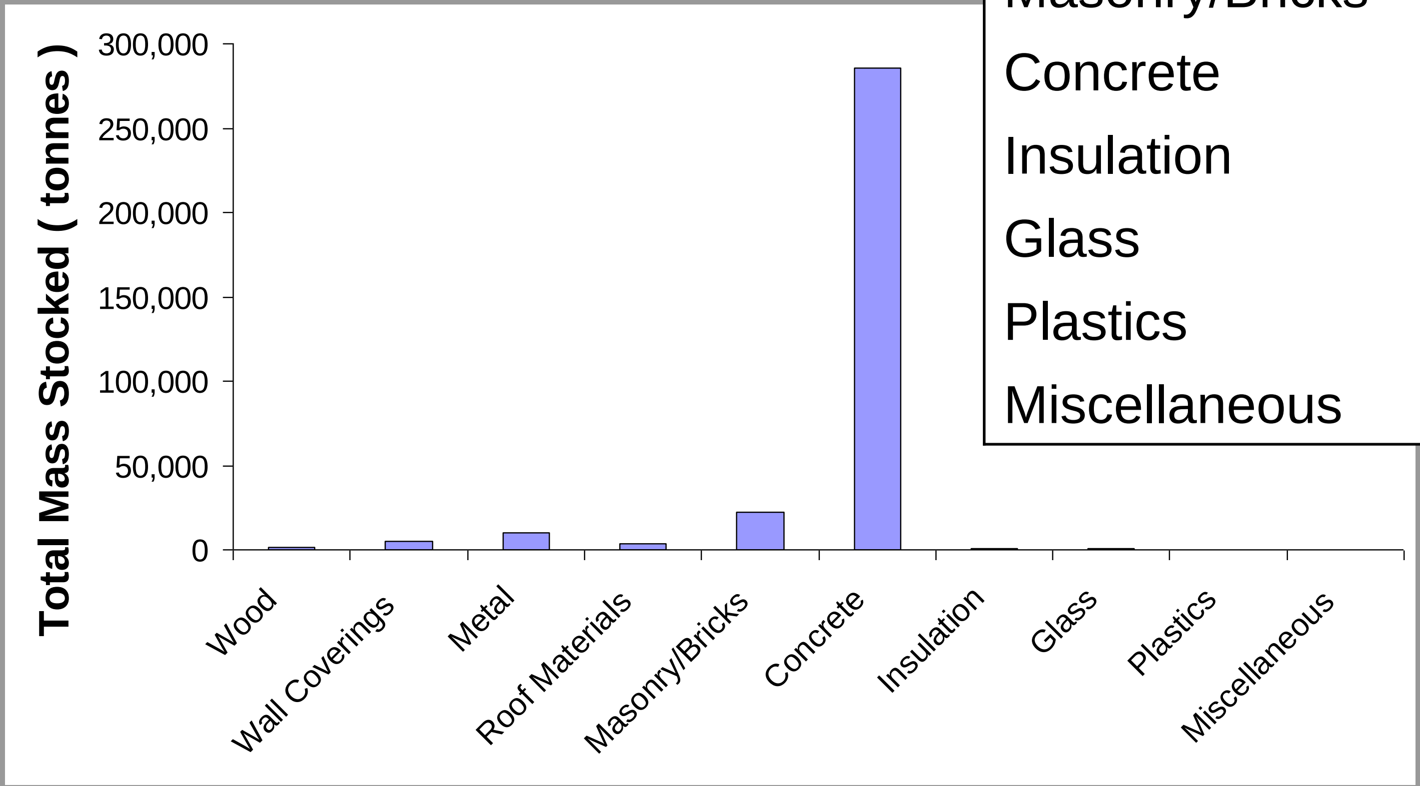
GLOBAL WARMING POTENTIAL

Ranked by metal



results

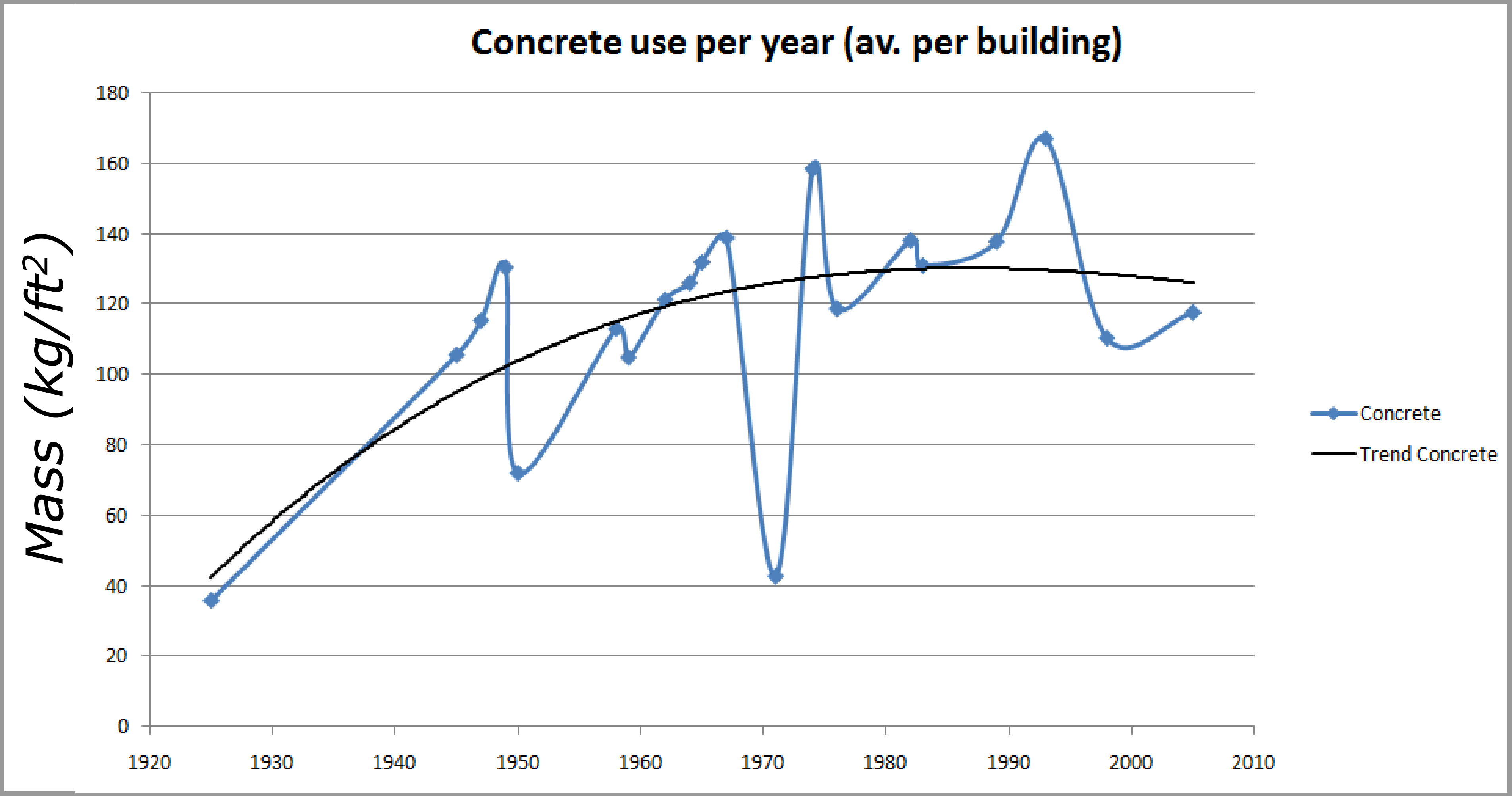
CONSTRUCTION MATERIAL STOCK AT UBC



Material Category	Total (tonnes)
Wood	1,161.68
Wall Coverings	5,258.71
Metal	10,194.95
Roof Materials	3,315.98
Masonry/Bricks	22,463.47
Concrete	285,582.99
Insulation	836.91
Glass	376.13
Plastics	34.18
Miscellaneous	8.82

results

CONCRETE CONSUMPTION



functional units

Categorize buildings by their functional units, in terms of:

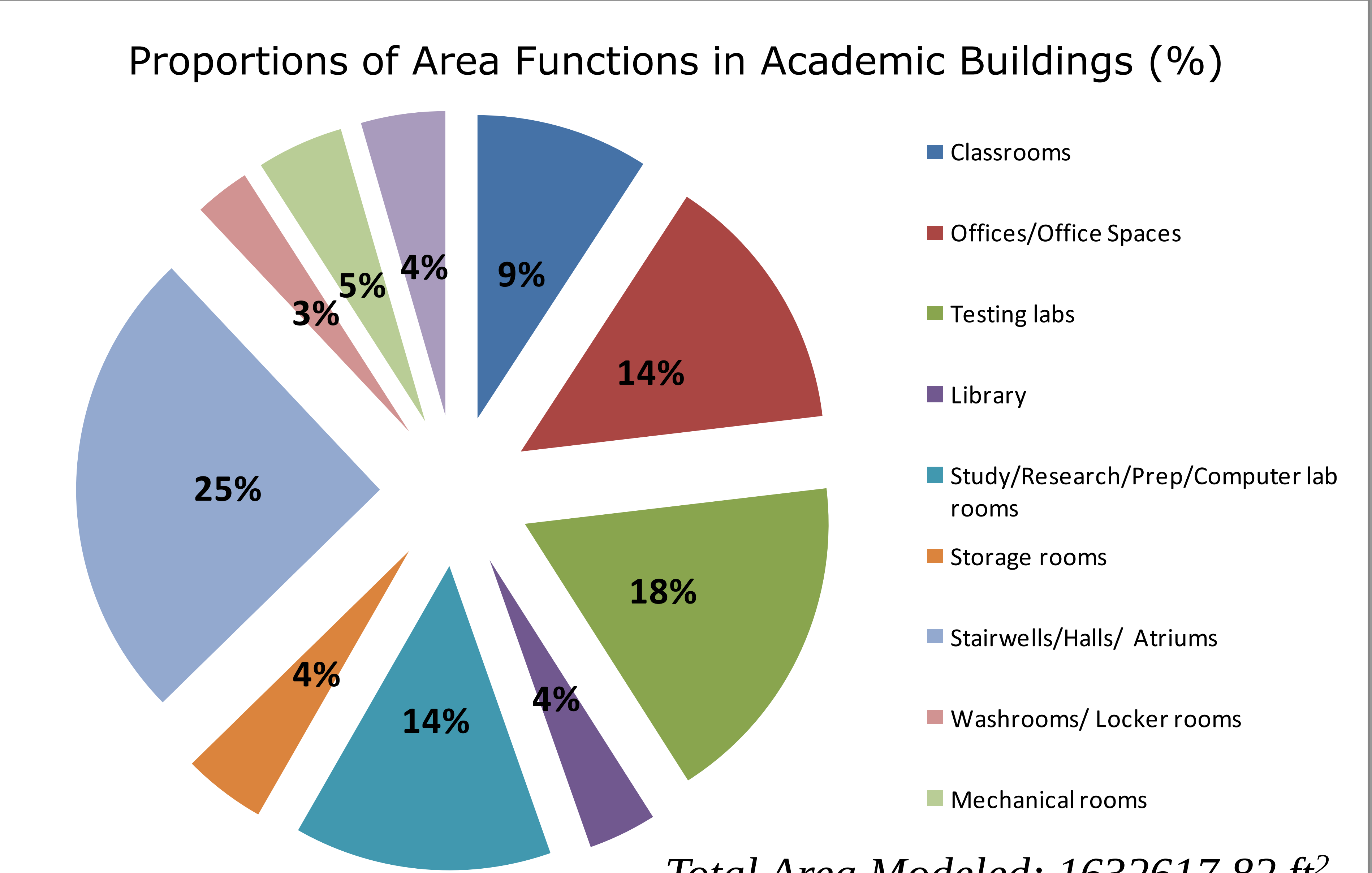
- Institutional, commercial or residential
- Number of classrooms
- Number of research labs
- Number of offices
- Study areas or halls
- Theatres

Challenges with defining functional units:

- Occupancy
- Productive use
- Number of floors in building
- Design
- Floor space

results

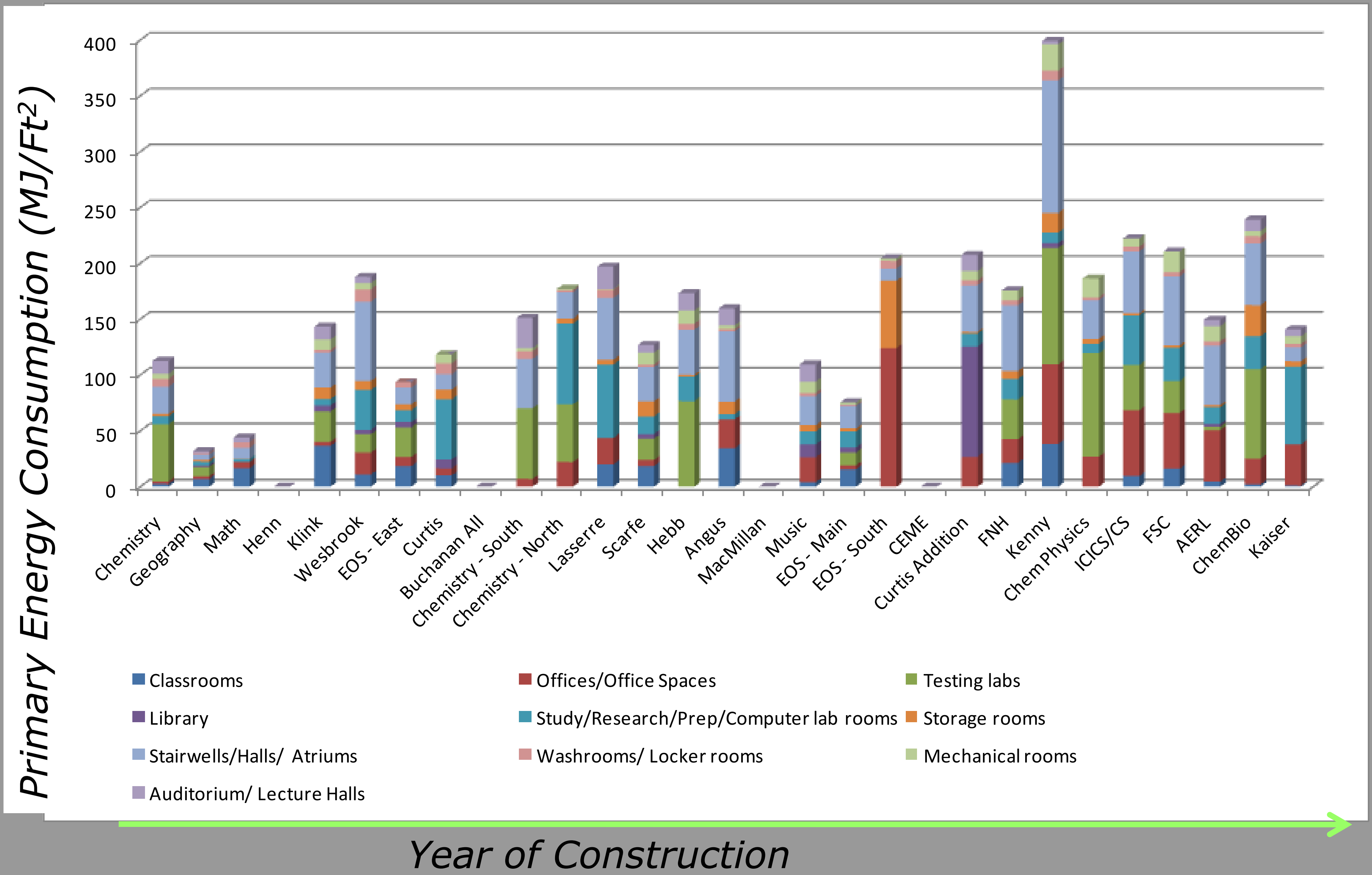
DISTRIBUTION OF ACADEMIC BUILDING FUNCTIONS



Total Area Modeled: 1632617.82 ft^2

results

IMPACTS DISTRIBUTED OVER FUNCTIONS

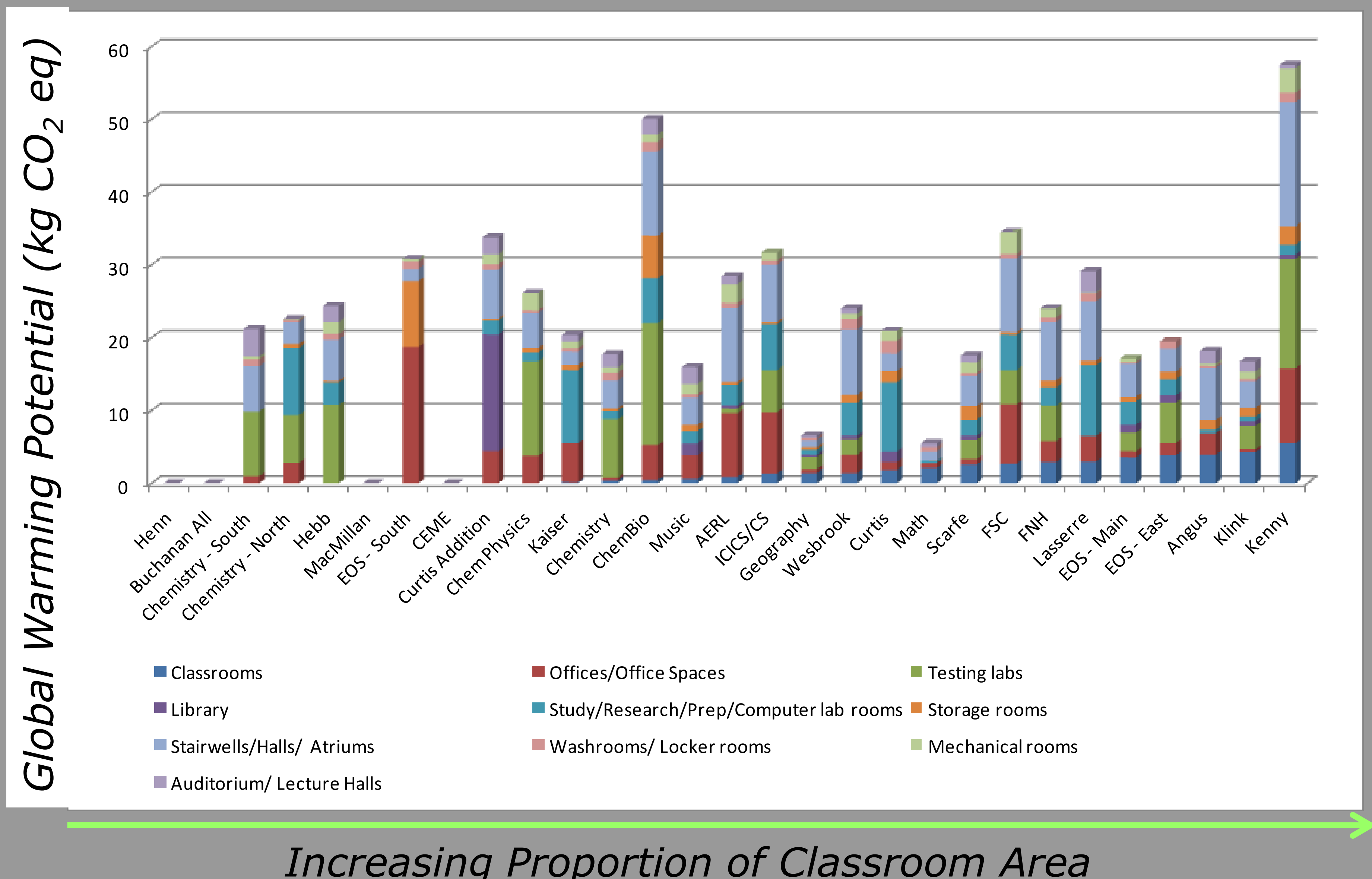


CIVL498C: LIFE CYCLE ASSESSMENT

results

GLOBAL WARMING POTENTIAL

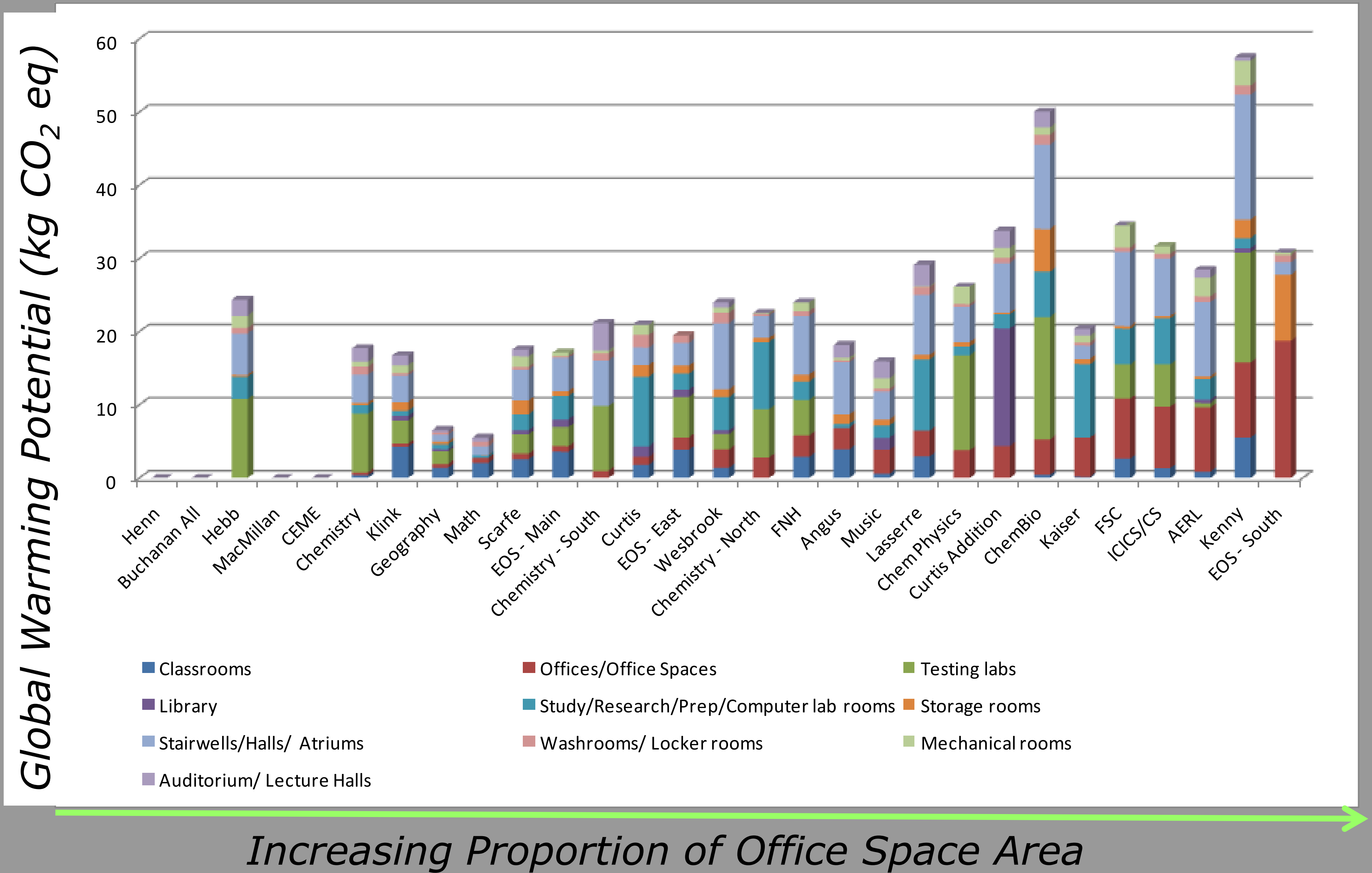
Ranked by classroom/total area



results

GLOBAL WARMING POTENTIAL

Ranked by offices/total area



Applications and Recommendations

Relevant to UBC and Beyond

applications of our study

Applications of our study ***relevant to UBC***:

- LCA Database (comparison purposes)
- Renovation baselines
- Effectiveness of green building policies

LCA database

WHY?

What do the Numbers Mean?

global warming potential =
500 kg/co2 equivalent/sf

Ozone depletion potential = **2.5 kg CFC-11 equivalent/ft^2**

Primary Energy Consumption = **59,340,113 MJ**

LCA database

WHAT IT CONTAINS

- 29 buildings from around UBC over the past two years have been studied and relevant information stored in the database.

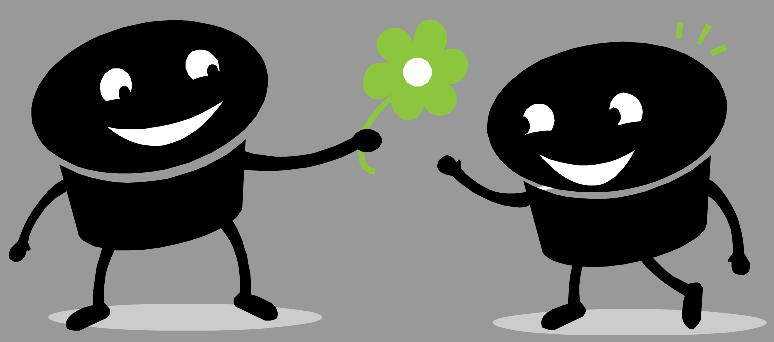
Each building has:

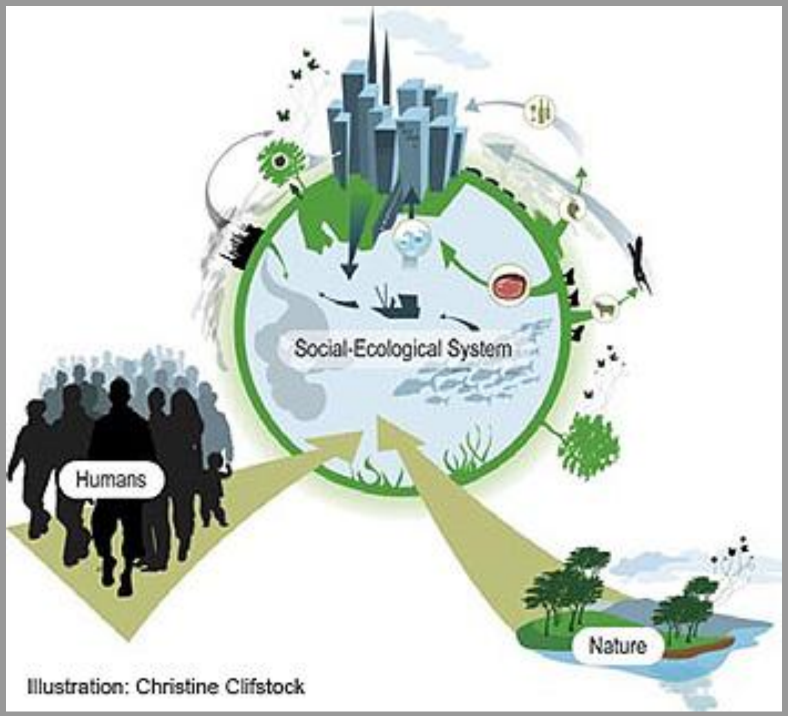
- Models
  - OnScreen TakeOff models
  - Inputs and Assumptions Documents
  - Impact Estimator models
- Results
  - Bill of Materials
  - Room Type info
  - LCI profiles
  - LCIA profiles

LCA database

RESEARCH PURPOSES

- Continue to grow database
- Learn from past and look for opportunities to reduce future burdens of construction
- SEEDS Program
  (Social, Ecological, Economic, Development Studies)





renovation baselines

RENO vs NEW BUILDINGS

Can be hard to convince decision makers, when their main concern is short-term monetary costs

Trek 2010, UBC Renew and UBC Policy #5, *Sustainable Development*, are visions for sustainable development

- LCA is a tool that could facilitate this vision

Our study could serve as baseline for renovations and demolitions being done (ie. Curtis, EOS-East, etc.)

renovation baselines

RENO vs NEW BUILDINGS

Most material from demolition and renovation go directly into the landfill.

Using the bill of materials from our study one would be able to estimate what wastes products will be created and could possibly be reused.

Further research:

- methods of reusing and recycling demolition waste
- how to preserve materials during deconstruction

effectiveness of green building policies

IMPACT ASSESSMENT PROFILE COMPARISON

GHG discussion paper

- Scope 1: Direct energy usage
- Scope 2: Electricity usage
- Scope 3: Other (includes transportation, buildings, etc.)

2006 GHG EMISSIONS INVENTORY

Scope	Source	Total Emissions
Scope 1	Natural gas	66,418
	Oil	455
	Fleet	2,248
Scope 2	Electricity	22,365
Scope 3	Buildings**	12,012
	Air travel	15,385
	Commuting	25,761
	Waste	1,065
	Paper	1,146
	Fertilizer	149

* Based on emissions factors that are subject to change

** Embodied energy in building construction

Scope 3 is currently not mandated …

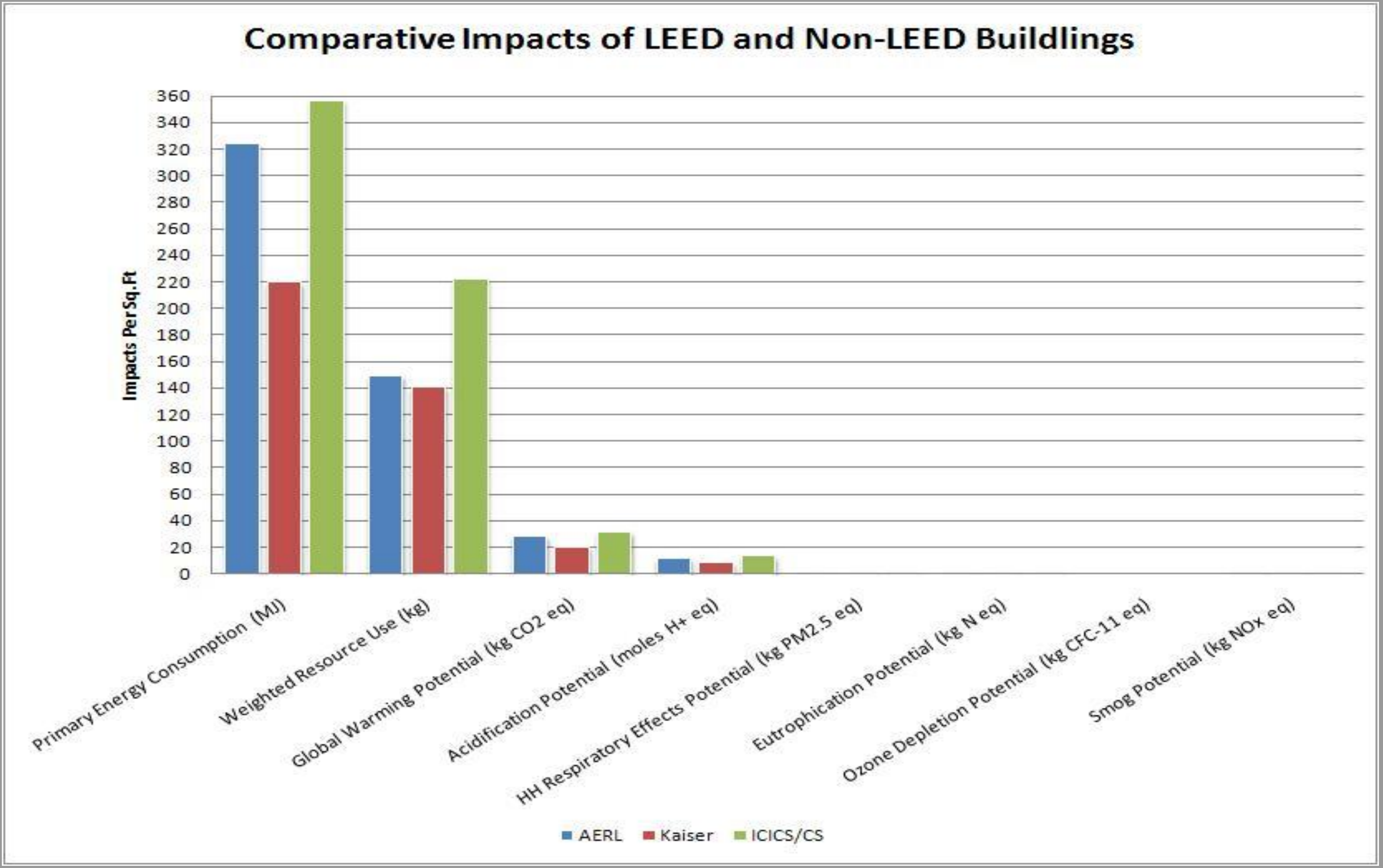
effectiveness of green building policies

IMPACT ASSESSMENT PROFILE COMPARISON

Was the decision to require LEED buildings an effective one vs cost of implementation?

effectiveness of green building policies

IMPACT ASSESSMENT PROFILE COMPARISON

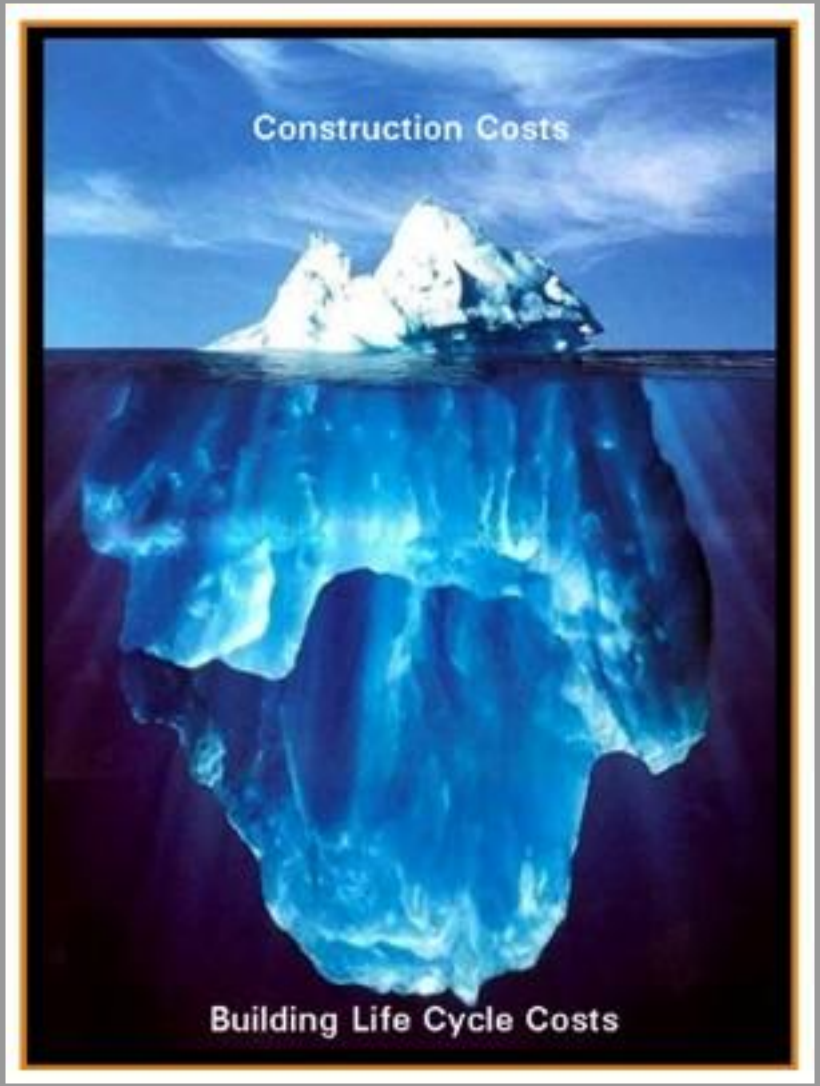


effectiveness of green building policies

OPPORTUNITY FOR IMPROVEMENT?

Regardless of effectiveness

Stop the focus on BRAND
Start the focus on full life cycle sustainability



effectiveness of green building policies

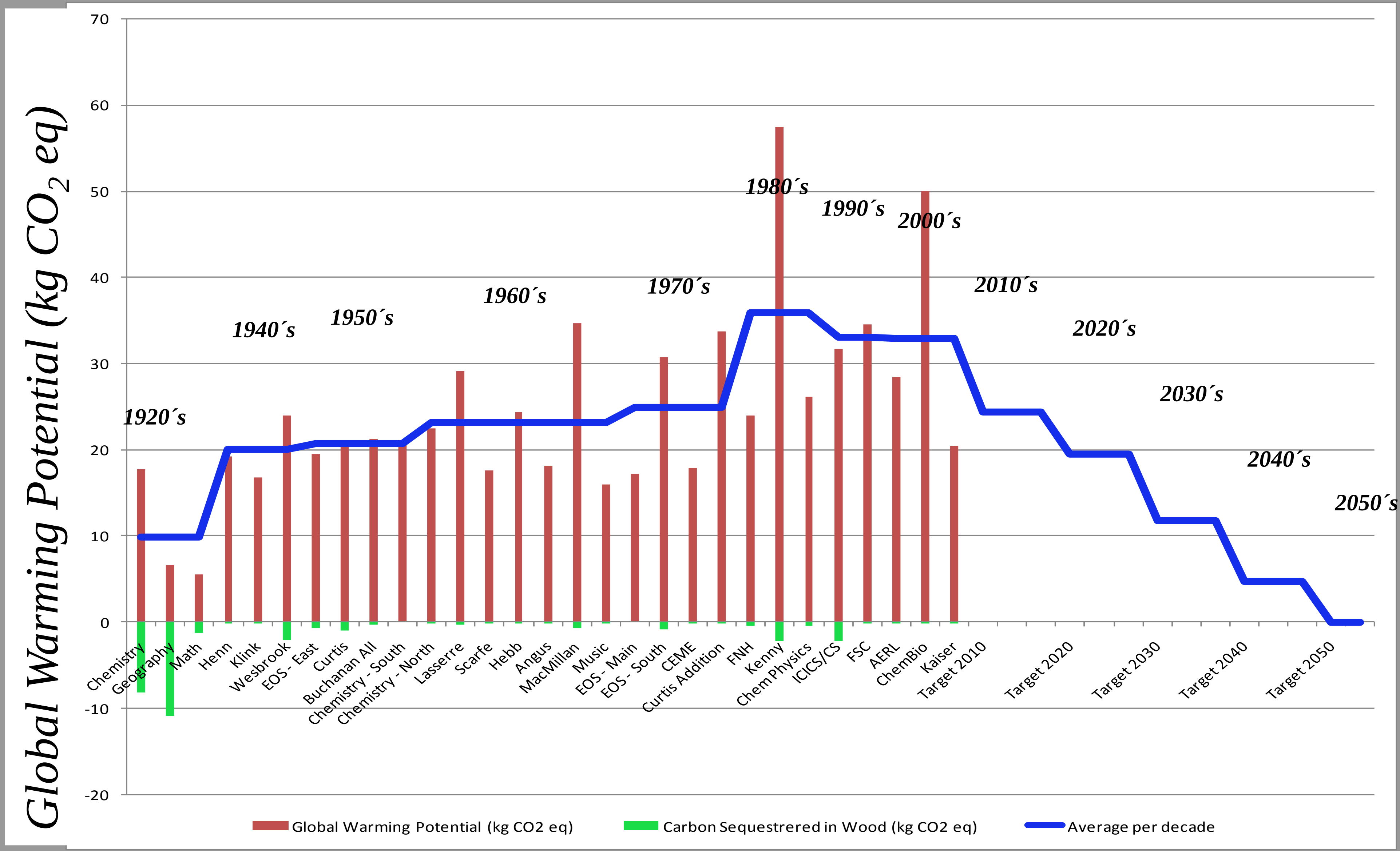
MOVING TO PERFORMANCE BASED GREEN BUILDING

“UBC is announcing aggressive GHG reduction targets. The university will now aim to:
- reduce GHGs an additional 33 per cent from 2007 levels by 2015
- reduce GHGs to 67 per cent below 2007 levels by 2020
- eliminate 100 per cent of GHGs by 2050”

(Stephen J. Toope, March 24th 2010)

effectiveness of green building policies

MOVING TO PERFORMANCE BASED GREEN BUILDING



effectiveness of green building policies

LCA INTO LEED

- May, 2009, LEED introduced an LCA pilot credit
- US Green Buildings Council suggests two main criteria for successful integration of LCA into LEED
    1. Consistency in collection and evaluation of LCA data
    2. LCA tools must be simple and user friendly to allow widespread use by designers

recommendations from our study

- Beyond manufacturing and construction
- Quantify uncertainties
- Collaboration
  - UBC Renew
  - Interdisciplinary
- Education
- Engagement

beyond manufacturing & construction

MORE BUILDING ELEMENTS

Consider more than structure and envelope of a building in LCA, such as:

- Plumbing
- HVAC
- Electricial
- Finishing Materials
- Permanent Furniture

beyond manufacturing & construction

COMPLETE LIFE CYCLE ASSESSMENT

- Consider maintenance, operation and end-of-life impacts
- Higher impact materials may result in greater long-term operational savings
- Ignoring further life cycle stages leads to false results

recommendations for our study

QUANTIFY UNCERTAINTIES

- Modeling
  - Older buildings with current data
  - Using averaged LCI profiles
  - Using non-regionalized impact assessment
- Implement a method for quantifying uncertainty in the inputs
- Athena does not allow the specific input of structural dimensions or building specific materials and assemblies adding additional uncertainty

collaboration – ubc renew

STANDARD PRACTICE DEVELOPMENT

- Collaborate with
  - UBC Renew to develop a standardized methodology for performing LCA in practice

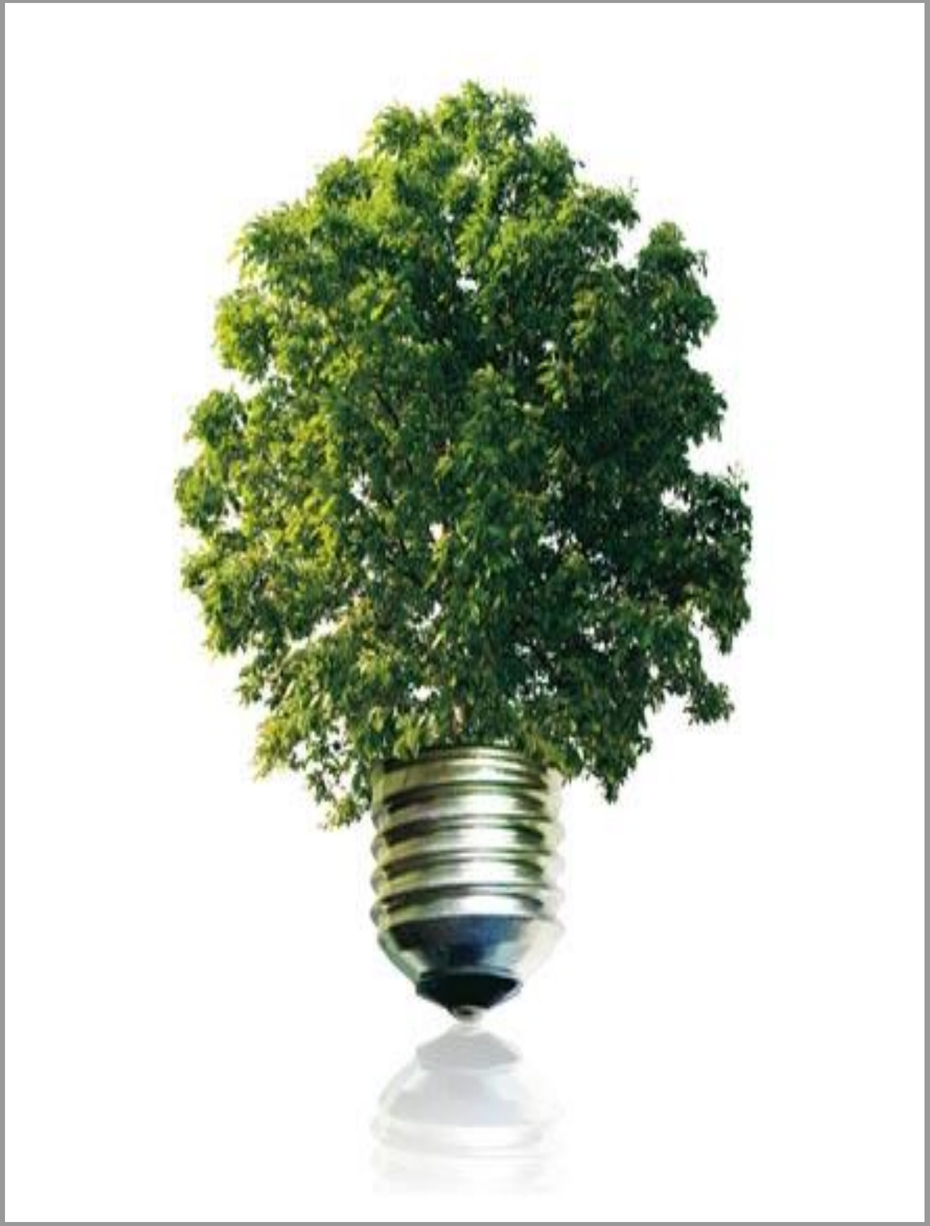
UBC RENEW PHASE II

UBC Renew is by definition sustainable building practice: the decision to renew rather than demolish and build new facilities avoids manufacturing new building materials and significantly lowered the environmental impact of the project saving: 96 million MJ of primary energy, 27 million L of water, 3.2 million kWh electricity, 492 metric tons of coal, and 1.5 million metric tons of construction waste were diverted from landfill. Proposed UBC Renew Phases Two through Five will renovate an additional 18 buildings by 2018. If all 5 proposed UBC Renew phases are completed for a grand total of $660 million, 136,650 GSM will be renovated, preventing emission of 21,344 metric tons of greenhouse gases.

collaboration - interdisciplinary

INCREASE STUDENT INVOLVEMENT

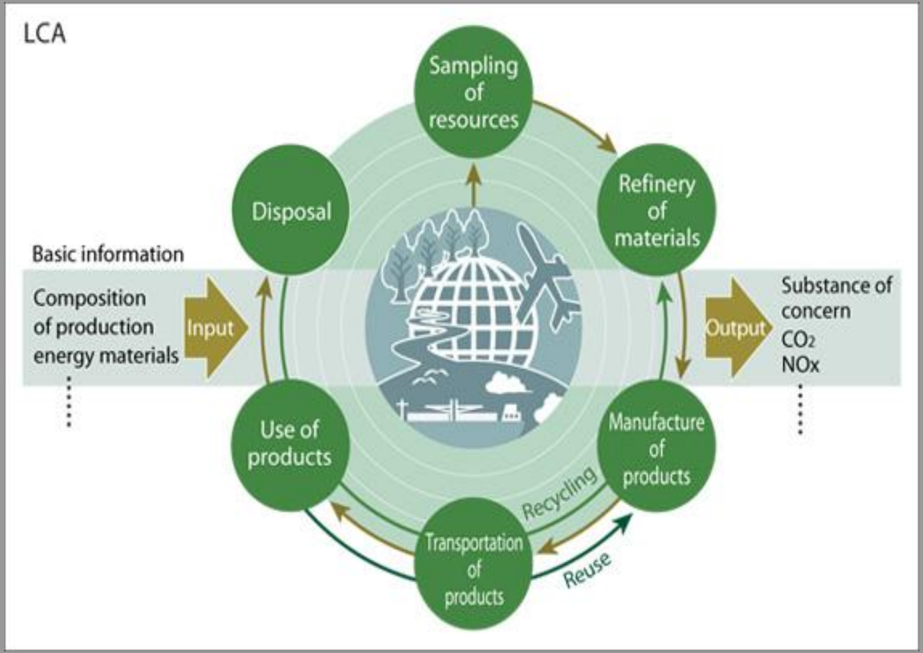
- Collaborate with
  - Mechanical Engineering students to create complementary energy models of UBC buildings
  - Planning students to create infrastructure models
  - Architecture students to reduce load on creating building models in the first place…
  - Other possibilities (biology, chemistry, atmospheric, ag sci, forestry, etc)



education

SPREADING THE KNOWLEDGE

- Use the study we are developing to educate and inspire
  - The UBC community
    - Students
    - Faculty
    - Staff
  - other institutions to join our study
    - Who's actually the most green!
  - firms in industry to consider the benefits of this method
    - Architectural
    - Engineering
    - Manufacturing
  - Government
    - Municipal to Federal



engagement

SPREADING THE USE OF THE KNOWLEDGE

- Show current and improved building performances
- By reaching out and providing
  - Posting study up online
  - Presentations, seminars and workshops
- Demonstrations of the extents LCA methodology, applications and power in providing effective direction towards sustainability

conclusions

OUR STUDY

- Study
  - 29 academic buildings
  - 2 software tools
  - Unlimited student patience
- Results
  - Quantified inventories and impacts
  - Role of materials
  - Different functions
  - Assumptions & limitations

conclusions

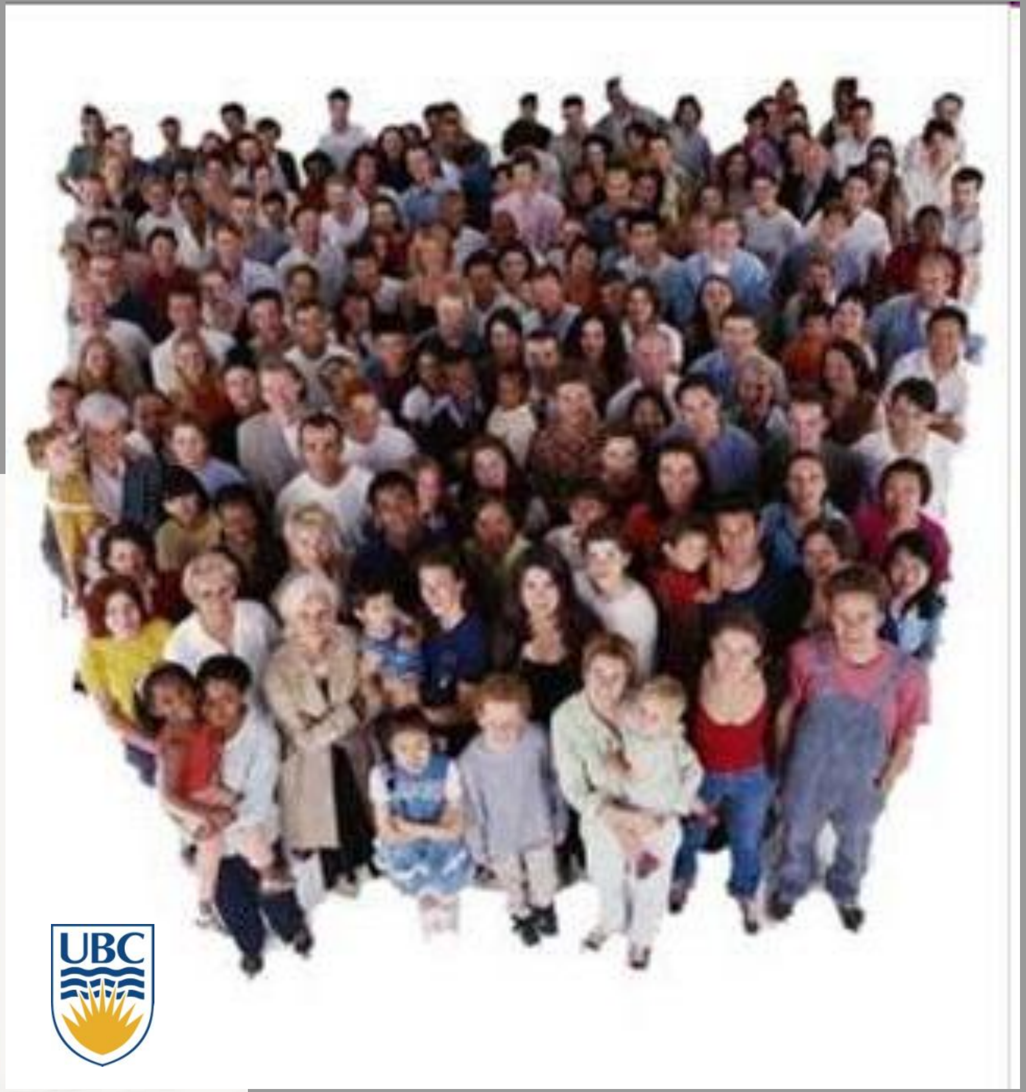
APPLICATIONS

- Applications
  - Database
  - Effectiveness
  - Policies & programs
    - Decision making

conclusions

RECOMMENDATIONS

- Recommendations
  - Expand & Improve
  - Education
  - Engagement



thank you

LET US KNOW YOUR THOUGHTS